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# PHYSICAL AND CHEMICAL
# ESSAYS:

TRANSLATED FROM THE ORIGINAL LATIN OF

**SIR TORBERN BERGMAN,**

KNIGHT OF THE ORDER OF WASA, PROFESSOR
OF CHEMISTRY AT UPSAL, &c. &c. &c.

**BY EDMUND CULLEN, M.D.**

FELLOW OF THE ROYAL COLLEGE OF PHYSICIANS
AT DUBLIN.

TO WHICH ARE ADDED

**NOTES AND ILLUSTRATIONS,**

BY THE TRANSLATOR.

BIBL. CO P. COLL. O N. ANIM. OXON.

## VOL. I.

LONDON:
PRINTED FOR J. MURRAY, N° 32. FLEET-STREET;
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MDCCLXXXVIII.

Quam ob rem, ſi qua eſt erga Creatorem humilitas, ſi qua operum ejus reverentia et magnificatio, ſi qua caritas in homines, ſi erga neceſſitates et ærumnas humanas relevandas ſtudium, ſi quis amor veritatis in naturalibus, et odium tenebrarum, et intellectus purificandi deſiderium; orandi ſunt homines iterum atque iterum, ut miſſis Philoſophiis iſtis volaticis et præpoſteris, quæ hypotheſes theſibus antepoſuerunt, et experientiam captivam duxerunt, atque de operibus Dei triumpharunt, ſubmiſſe, et cum veneratione quadam, ad volumen creaturarum evolvendum accedant; atque in eo moram faciant, meditentur, et ab opinionibus abluti et mundi, caſte et integre verſentur.—In interpretatione ejus eruenda nulli operæ parcant, ſed ſtrenue procedant, perſiſtant, immorentur.

BACO DE VERULAMIO.

TO THE

ILLUSTRIOUS

ROYAL SOCIETY OF

LONDON,

THIS FIRST VOLUME OF

ESSAYS

IS DEDICATED,

AS A PROOF OF RESPECT,

BY THE AUTHOR,

WHO HAS BEEN A FELLOW

FIFTEEN YEARS.

UPSAL, 1779.

# TRANSLATOR's

# PREFACE.

TO enlarge on the literary abilities of the illuſtrious Author of the following Work would be unneceſſary: an aſſemblage of philoſophical qualifications, very rarely found united in one perſon, has long ſince ſufficiently eſtabliſhed his reputation. But among the many endowments of this great philoſopher, none is more conſpicuous than the anxious concern he every where diſcovers for the advancement of human happineſs, and the earneſtneſs with which he applies the great powers of his mind to ſuch points as may be immediately applicable to the uſes of life. He deſpiſes barren and unproductive ſpeculation; he conſiders ſcience as deſirable only ſo far as it is beneficial; and proves himſelf, upon every occaſion, not only the Teacher, but the Friend of mankind.

Works like thoſe of Mr Bergman ſhould have an univerſal circulation; they are written not to the ſcholar alone, but to the artiſt, to the manufacturer, and to the world in general. In preſenting the following pages, therefore, to the Engliſh Reader, the Tranſlator flatters himſelf he is acting in perfect conformity with the ſentiments of the Author, and the duty which, as an individual, he owes to the community.

As the Author writes chiefly to thoſe converſant in chemiſtry; and as it requires more than a moderate acquaintance with ſome of the lateſt diſcoveries, to be able to follow him through the whole of the Work; it has been judged neceſſary to add a few explanatory notes, ſuch as may render the book uſeful to thoſe who are only acquainted with the elements of the ſcience. An Appendix is accordingly ſubjoined to each volume, which, though by no means neceſſary to the accompliſhed and experienced chemiſt, will, it is hoped, prove conſiderably uſeful to the general run of readers, and thoſe who are but moderately ſkilled in the knowledge of the chemical principles and art.

Mr Bergman, in his experiments, has employed the Swediſh thermometer: and it has not been thought expedient to reduce the temperatures, ſo aſcertained, to Fahrenheit's ſcale in the body of the Work, becauſe the degrees upon the Swediſh thermometer are not reducible to integral numbers upon that of Fahrenheit; but, for the accommodation of ſuch as chuſe to compare them, a plate is inſerted, containing the Swediſh and the French thermometers, together with that of Fahrenheit, which is at preſent univerſally employed in England.

The Swediſh meaſures being alſo ſo adjuſted that they are not reducible exactly to thoſe of England, have been ſuffered to ſtand as in the orginal; but a table is given, which contains theſe weights and meaſures accurately reduced.

ADVER-

# ADVERTISEMENT.

*THE great diſtance of the Tranſlator obliged the publiſher to call in the aſſiſtance of another perſon to ſuperintend the preſs. That perſon, being unacquainted with the tranſlator's deſign of adding annotations at the end of the volumes, was induced to add a few inconſiderable obſervations, ſuch as his recollection could furniſh, during an haſty peruſal of the MS. He, moreover, thought, that the addition of M. De Morveau's notes would be acceptable to the Engliſh reader. He accordingly has ſelected ſuch as afford any new views of the facts related by the Author, or ſupply any experiment by which the text is illuſtrated. He has omitted ſeveral that did not ſeem to contain much uſeful information. That no blame might be imputed to the Tranſlator, on account of theſe additions, he has been careful to diſtinguiſh thoſe of M. de Morveau by his name: his own by the letter* B. *Thoſe marked* C. *belong to the Tranſlator; who has been obliged, on account of ſome domeſtic interruption, to defer the greater part of his remarks to the end of the ſecond volume; which will appear without delay. The Author's notes and references are without a ſignature.*

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*Quid verum — — curo et rogo, et omnis in hoc ſum.*
HOR.

This Diſſertation was read in 1774, before the Royal Academy of Sciences at Upſal; and the year following it was printed in the 2d vol. of the New Tranſactions.

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The firſt ſeven ſections of this Diſſertation were publicly defended by J. P. Scharenberg of Stockholm, on the 26th of June, 1778.

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This Diſſertation was publicly defended by C. H. Wertmüller, of Stockholm, on the 15th of December 1773.

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*Opinionum commenta dies delet, judicia naturæ confirmat.*

CICERO.

This Diſſertation was defended by C. Norell, on the 23d of December 1775.

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OF

# OF THE

# INVESTIGATION

# OF

# TRUTH.

THE great difficulty attending the inveſtigation of truth, muſt be known to every man who has ever ſeriouſly attempted it. *Involutam veritatem in alto latere*, was long ſince obſerved by the experienced Seneca.

With reſpect to ſuch hiſtorical facts as are remote from our times, modern ſcepticiſm frequently exceeds all bounds, and determines arbitrarily what are to be conſidered as fictions, what as miſrepreſentations, and what as omiſſions. But we ſhall ſoon ceaſe to wonder at this; for if we undertake, on the faith of others, to explore facts, which, even with reſpect both to time and place, are at hand, and almoſt under our immediate inſpection, (eſpecially if we wiſh to learn the cauſes, motives, and connections of actions and circumſtances), we are often confounded by the moſt contradictory narrations, inſomuch that we have occaſion for opportunity and laborious ſtudy, muſt diveſt ourſelves of preconceived opinions, and be unbiaſſed by any intereſted motives, in order to ſolve a number of difficulties, which owe their origin partly to ignorance, partly to negligence, and not unfrequently to deliberate malice. Should a number of hiſtorians even agree concerning a fact, yet the different deſcriptions of it will, to a certain degree, exhibit the characters of the reſpective authors:—Thus, while one relates an action with the moſt extravagant encomiums, another will detract from its real merit—a third, by ſome oblique inſinuation, caſt ſuſpicion upon the motive of it—and a fourth repreſent it as a crime of the blackeſt dye. But to quit this line of inquiry.—It may be expected that we ſhould find things otherwiſe in phyſics, and that, though we may not be able to dive into the thoughts of men, the phænomena exhibited by nature would be liable to no ſuch ambiguity.

So indeed it might ſeem, did not daily experience fully evince the contrary. Among the moſt celebrated expounders of nature, how many diviſions have there been? how many ſchiſms? and what numbers do we find ſpringing up every day?

But when we examine theſe diſputes more minutely, we ſhall find that they relate not ſo much to facts, as to explanations. The labour of the natural philoſopher is chiefly employed in endeavouring to diſcover the means and the methods made uſe of by Nature in her operations, (that is, cauſes and their connections), and from thence to form what is called a theory; and upon this point has ariſen wonderful diſſenſion.

Des Cartes, aſſuming matter and motion, and thus beginning *ab ovo*, conſtructs the world, imagines certain forms and affections of bodies; and, led away by a ſublime imagination, connects and demonſtrates mechanically, *a priori*, every phænomenon and every operation. A ſtupendous work indeed, were it but conformable to the ſyſtem of nature, which it undertakes to explain; but, upon compariſon, ſo great a diſagreement appears, that in circumſtances where, according to the principles of the inventor, the moſt powerful cauſe is operating, there, in reality, is the ſmalleſt effect produced; and reciprocally. This whole imaginary ſtructure, therefore, being reared without foundation, has neceſſarily fallen to ruin.

The immortal Newton next appeared. This illuſtrious perſonage, rendered cautious by the failure of his raſh predeceſſor, acknowledges that a conception of the theory of creation exceeds human powers: He therefore follows the inverſe method. He firſt ſolicitouſly collects facts; theſe he examines with accuracy, and compares with acuteneſs: Hence he deduces the laws of nature, and, from effects well eſtabliſhed, he infers their cauſes. Thus he proceeds, more ſlowly indeed, but more ſecurely; and though his method be tedious, yet it is continually leading to further diſcovery. An edifice like this, built on a ſolid foundation, becomes the more firm the higher it is raiſed.

Although, at preſent, it is univerſally agreed, that nothing is known concerning bodies *a priori*, but that their nature and different properties muſt be diſcovered *a poſteriori*, by obſervation and experiment; nevertheleſs, in practice, there are ſtill not a few who, if not publicly, at leaſt privately, incline to Carteſianiſm. I call it Carteſianiſm, not becauſe that method of reaſoning was invented by Des Cartes, (for in the moſt remote periods of time, there have been philoſophers who, confiding too much in their own ſtrength, have expected to be able to diſcover the nature of things by abſtract meditation); but I employ the names of Des Cartes and Newton as affording the moſt ſtriking examples of the different methods of philoſophizing.

I have ſaid, that a tendency to Carteſianiſm ſtill ſubſiſts; and, upon attentive conſideration, it will not appear wonderful that the human mind ſhould delight to indulge in this method; for, on the one hand, the way of experiment is expenſive, troubleſome, and tedious. All minds, therefore, are not capable of enduring it: Many are without the proper inſtruments; others want the neceſſary dexterity; but the moſt univerſal defect is that of patience and perſeverance; ſo that if the experiment does not at once ſucceed, it is abandoned in diſguſt. Man, in his ordinary ſtate, ſeems by nature prone to indolence. On the other hand, the contemplative method favours the deſire of knowledge; by pretending to unlock the ſecrets of nature with eaſe and expedition, it ſoothes the natural rage of explaining all things; and, by ſuppoſing every thing acceſſible to the human intellect, adminiſters pleaſing flattery to vanity and arrogance.

At preſent, however, the neceſſity of experiment appears ſo obvious, that no one can deny it, without expoſing himſelf to ridicule. It is therefore acknowledged, but with a tacit limitation. A number of experiments, made during a ſucceſſion of ages, is collected; and an accurate and attentive conſideration of them is thought ſufficient to unravel the chain of cauſes. Thus a philoſopher at his table, ſurrounded with books, undertakes to penetrate the arcana of nature, and to deal out truths as if by inſpiration; and, without a laboratory, without a ſuitable apparatus, without expence, trouble, or danger, pronounces concerning ſubſtances, which, far from examining as he ſhould, he has never ſo much as ſeen. Nor has this invention even the recommendation of novelty; for, many ages ſince, Ariſtotle eſtabliſhed experiment and reaſoning as the two foundations of natural philoſophy; but by means of the latter he miſerably corrupted the former. In this way, at preſent, the purity of truth is corrupted by preconceived opinions concerning the geneſis and metamorphoſis of matter.—Opinions ſuch as theſe, if modeſtly and candidly propoſed as conjectures, might be uſeful, by giving occaſion to new experiments; but are of the moſt pernicious tendency when obtruded as axioms; when they wreſt ſuch experiments as contradict them to a conſtrained agreement; or, if that cannot be done, impugn the truth of the experiments. Another evil has originated from favourite hypotheſes, namely, experiments mutilated, and not to be relied on. He who is governed by preconceived opinion, may be conſidered as a perſon viewing objects through coloured glaſſes, each aſſuming a tinge ſimilar to that of the glaſs employed. The ſlighteſt and moſt vague ſimilitudes, if agreeable to the ſyſtem, are ſufficient, nay, afford arguments of the greateſt weight; while differences of the moſt ſtriking nature are diſregarded as altogether nugatory.

The time which is employed in diſcuſſing theſe trifles, would ſurely be better applied in experiment and obſervation; a labour by which truth may be made to ſhine forth in full luſtre, and due honour be given to ſcience, which now (tarniſhed by contradictions and diſſenſions) is, if not totally deſpiſed, at leaſt ſuſpected by thoſe who are incapable of deep inquiry.

Add to this, that, even in natural philoſophy, the turbulent paſſions of the mind are not always idle: Sad experience has ſhewn us the moſt beautiful inventions brought into contempt, and the higheſt merit blaſted, by malignant clamour. But our buſineſs is not with thoſe who are wilfully blind to truth; to argue with ſuch would be to tell tales to the deaf.

Since then truth is, or at leaſt ought to be, the end of every inveſtigation, to obtain this end with eaſe and expedition—*hoc opus, hic labor,*—I think it therefore neceſſary, at the beginning of this Collection of Eſſays, to explain to the reader the principal rules which, in the progreſs of them, I laid down for myſelf. In the examination of any body, two circumſtances are chiefly to be conſidered, namely, *the compoſition of that body*, and *the explanation of phænomena.*—Theſe two we ſhall conſider ſeparately.

I. (A) *In inveſtigating the principles of a body, we muſt not judge of them from a ſlight agreement with other known bodies, but they muſt be ſeparated*

*ted directly by analyſis, and that analyſis muſt be confirmed by ſyntheſis.*

It is well known that bodies, by compoſition, acquire new properties, which did not appear in any of the component parts ſeparately; and, on the contrary, ſome of the original properties decay, or even diſappear: Hence it appears how little analogy is to be truſted to.

Thus, although terra ponderoſa and magneſia agree with lime in this particular, that, when united with aerial acid, they efferveſce with other acids; and that, when it is expelled, they become cauſtic, we are not hence to conclude that lime is contained in thoſe ſubſtances. This analogy is certainly a looſe one, and, when rightly conſidered, only ſhews that the aerial acid poſſeſſes the property of uniting with a variety of ſubſtances, and that by its preſence cauſticity is repreſſed. If we were to deduce concluſions from this analogy, then the alkaline ſalts muſt contain lime, as they alſo efferveſce with acids, and, in ſimilar circumſtances, exhibit a much greater degree of cauſticity.

The hiſtory of the learned world ſhews us the abſurd arguments which were formerly made uſe of againſt the exiſtence of the foſſile alkali, which is now acknowledged by every one to exiſt diſtinct from the vegetable alkali, inaſmuch as, when combined with the acids, it never fails to produce ſalts of a different ſort. In the ſame manner terra ponderoſa and magneſia, with acids, yield ſalts very different from thoſe produced by lime with the ſame acids: We may therefore conclude theſe to be diſtinct ſubſtances.

That perhaps they contain a lime ſomehow changed, I will readily acknowledge, as ſoon as lime can be extracted from them, or they can be converted into lime. Conjectures the moſt plauſible are yet at a diſtance from truth, and, upon cloſe examination, are frequently found altogether repugnant to it.

What has now been ſaid holds, *mutatis mutandis*, of aerial acid and the acid of ſugar; as alſo of nickel, cobalt, and manganeſe.

In general, any body which differs in properties from every other, and can be always had *ſimilar to itſelf*, I conſider as a different and diſtinct body, although it be produced by another known body; for properties new and conſtant cannot ſpring up, unleſs the primitive be changed by the addition or ſubtraction of ſome principle, in which caſe it is not the ſame body as before.

(B) *Analyſis ſhould chiefly be conducted in the humid way.*

I do not deny, but that the dry way may ſometimes be uſeful, and ought to be employed; but, in moſt caſes, fire tends rather to confound than to ſeparate different ſubſtances.

Some contend that matters extracted by menſtrua are changed, and that they had exiſted in the decompoſed body in a ſtate very different from that in which they are found after the decompoſition; but, let us not reſt upon vague aſſertion; let us inquire into the truth by experiment, and our doubts will ſoon vaniſh:—Let us diſſolve a given quantity of pure chalk in marine acid; let this again be precipitated by a fixed alkali; and if this alkali be mild, the chalk is recovered entirely ſimilar to itſelf in properties and in weight: But, if the alkali employed be cauſtic, not more than half the weight is obtained, and the precipitate agrees with lime burned and ſlacked; for it is ſoluble in water, and raiſes no efferveſcence in acids. This experiment, if repeated an hundred times with the ſame chalk, will always afford the ſame product. The ſame thing is true of terra ponderoſa and magneſia, and alſo pure clay, of which the weight, however, is ſcarce ſenſibly altered by a difference in the precipitant. The ſame holds in the other acids. Let us now diſſolve ſome metal, precipitate with a fixed alkali, and we ſhall have a calx of that metal; but, if we precipitate with another metal, we ſhall recover the diſſolved metal itſelf, only very minutely divided. Mild alkali, in certain caſes, produces a much heavier calx than the cauſtic, namely, when the calx abſorbs the aerial acid: Beſides, the different acids occaſion, in this caſe, no other difference than a greater or leſs privation of phlogiſton. Theſe things, of which no one converſant in chemiſtry is ignorant, being known, let us ſuppoſe either lime, magneſia, clay, or iron, extracted by any acid menſtruum; I aſk, can we reaſonably doubt whether theſe ſubſtances actually exiſted in the body ſubjected to the experiment, or not? From the qualities of the integrant body, it will eaſily be judged whether theſe have entered into its ſtructure, mild or cauſtic; in the form of a calx, or in that of a metal.

Upon this occaſion, I muſt mention the inveterate error concerning the origin of vegetable alkali by fire. The ſilly and abſurd reaſons on which they denied the prior exiſtence of that ſalt, may now be retorted upon the authors.

(c) *Such experiments ſhould be inſtituted as are adapted to the diſcovery of truth.*

Light is thrown upon a ſubject not by the multitude, but by the quality of experiments: Moſt commonly many different points are to be illuſtrated, and then the experiments ſhould be varied according to circumſtances, ſo as clearly to aſcertain the point in queſtion.

For example, in examining the mineral fluor, one queſtion ariſes concerning the acid inhering in it, another concerning the baſis. To obtain the firſt, pure vitriolic acid muſt be applied in leſs quantity than is ſufficient to expel it all, and a degree of heat applied leſs than what is ſufficient to volatilize the vitriolic acid. In examining the baſe, the fire muſt be more intenſe, and a large quantity of vitriolic acid poured on, that no part may eſcape its action, which, mixed with the baſe, might obſcure its true nature: Thus, unleſs the operations and the means be adapted to the end propoſed, we only every day accumulate miſtakes.

(D) *Experiments ſhould be made with the utmoſt poſſible accuracy.*

Experiments which are only careleſsly and ſlightly obſerved, frequently either do not illuſtrate the truth, or eſtabliſh errors. By weight, by meaſure, and other fit means, all the principal circumſtances ſhould be ſettled, and all the phænomena carefully obſerved. With reſpect to facts, indeed, which are collected by experiment, no diſpute can ariſe, as they may at pleaſure be appealed to, and conſidered in every point of view with ſufficient care. The caſe is otherwiſe with thoſe circumſtances which depend ſolely upon the operations of nature; for theſe, if the fit time be neglected, do not again occur, but accidentally, or perhaps after an interval of years. "*Fronte capillata, poſt eſt occaſio calva.*" In many caſes, however, imitation may be able to diminiſh that interval.

I am almoſt aſhamed to relate, that I knew a chemiſt who conſidered thermometers, and ſuch inſtruments, as phyſical ſubtleties, ſuperfluous and unneceſſary in a laboratory. It is beyond a doubt, that the moſt minute circumſtances have their efficient cauſes; and theſe cauſes, for the moſt part, are ſo interwoven with the more powerful ones, and ſo moderate their efficacy, that, without the former, the whole effect cannot be appreciated. In natural philoſophy, no obſervations are trivial, no truths inſignificant. That which to us is barren, is often ſo for this reaſon only, that we do not ſufficiently know, nor ſufficiently examine it. How many millions had uſeleſsly beheld the falling of a pear; yet, to Newton, this moſt common of all phænomena ſuggeſted the theory of gravitation.

(E) *The experiments of others, particularly the more remarkable ones, ſhould be candidly reviewed.*

We ſhould never diſtruſt the experiments of authors of credit; but I hold it uſeful to have new inventions confirmed by many witneſſes in different places, which opens a wide field to induſtry.

It muſt be confeſſed, that many things occur which are more clearly and better underſtood by being ſeen, than by the moſt exact deſcription. In repeating any of Margraaf's experiments, I never entertained even the ſmalleſt doubt of the event. The accuracy, the dexterity,

rity, and ſound reaſoning of that chemiſt are known to every one inſtructed in theſe matters; nevertheleſs, I have repeated many of them, not without advantage. He who, at his deſk, meditates on the ſaccharine acid, readily concludes it to be ſugar diſſolved in the nitrous acid, and afterwards cryſtallized; but, better inſtructed on making the experiment, he changes his opinion, and learns not to give judgment raſhly upon the experiments of others.

One thing particularly neceſſary is candour, in obſerving with equal eye thoſe facts which controvert our opinions, and thoſe which favour them. It is well obſerved by the celebrated Morveau, that we never profit more than by thoſe unexpected events of experiments which contradict our analogies and theories: It often happens, however, that he who ſees the better, follows the worſe. Thus he who denies that the earth of vegetables, ſeparately taken, is not a compound body, yet grants that a part of it is ſoluble in acids, confutes himſelf with his own argument; for, of an homogeneous maſs, either the whole or none muſt be taken up.

II. The phænomena of a body, either conſidered by itſelf, or in reference to other bodies, have their foundation either in the body itſelf, or in external circumſtances. The explanation of theſe, then, muſt be ſought for,—" *bene ſcire,*

“ *eſt per cauſas ſcire.*” Theſe being rightly known, the nature and properties are clearly underſtood, and may be moulded to our wiſh. The greateſt care, however, muſt be taken not to embrace falſehood for truth—therefore,

(A) *In the inveſtigation of cauſes, we muſt begin by phænomena ſufficiently varied, and well obſerved; and proceed in order, from proximate cauſes to the more remote.*

The quantity and quality of a cauſe are to be judged from its effect; hence the better that is known, the more nearly can thoſe be determined. This way is extremely laborious and troubleſome, and, beſides, very tedious; inſomuch that we are often found to confeſs the cauſe of this or that phænomenon to be yet unknown: But the laws by which a cauſe is governed in its operations, being once eſtabliſhed, we are at liberty, in many caſes, to aſſume the cauſe, as if known; and I had rather, with Newton, ingenuouſly confeſs my ignorance, and know few things, but theſe certain and determinate, than, with Des Cartes, explain every thing upon forged or falſe principles. Cicero long ſince ſaid, “ *præſtat naturæ voce doceri* “ *quam ingenio ſuo ſapere.*”

By how trifling an appearance, if it be a pleaſing one, we may be deceived, the following example will ſhew:—It is known, that lime, well burned, has loſt the property of efferveſcence with acids. This phænomenon is troubleſome to many who deny the exiſtence of aerial acid.. At length, however, an evaſive expedient was ſuppoſed to be diſcovered, namely, if burned lime be put into highly concentrated acids, a viſible efferveſcence is ſaid to take place, which, when the acids are weak, cannot be ſeen, as the ſubſtance, being dried by the fire, readily abſorbs them. In order to clear up this miſtake, it is only neceſſary to obſerve the phænomena with accuracy :—Let a ſmall glaſs veſſel be filled with nitrous acid, throw into it a piece of chalk, immediately innumerable bubbles are emitted from its whole ſurface, which continue while a ſingle particle remains viſible ; during this violent agitation a thermometer, dipped into the glaſs, ſhews not the ſlighteſt alteration of temperature (*a*). Whether the acid be diluted or

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(*a*) M. Morveau, in a note, which I have tranſlated (ſee p. 38), truly obſerves, that when chalk is diſſolved in a concentrated acid, heat is produced. The author himſelf (*Opuſc.* vol. iii. p. 64.) ſays, that calcareous earth, while it was diſſolving in nitrous acid, raiſed the liquor in the Swediſh thermometer from + 14° to + 20°, and lime, not ſlacked, from + 14° to + 84°. He attributes the miſtake in the text to his having made the experiment with too ſmall a quantity of materials, and having employed a thermometer not ſufficiently ſenſible.

or concentrated, the ſame phænomena occur: Let now the experiment be repeated, only, inſtead

In the ſame note, M. Morveau gives an explanation, undoubtedly erroneous, as I have there obſerved, of the heat and cold produced in chemical experiments. Sir T. Bergman has aſſigned the true theory in his third volume. He has deduced it from the different quantity of *ſpecific* fire, or, according to his mode of expreſſion, of *matter of heat*, contained in different ſubſtances: "The menſtruum," ſays he, "deſtroys the preſent aggregation of particles, and a new compound is formed, which ſometimes fixes a greater quantity of the matter of heat than the former compound; in this caſe, in order to reſtore the equilibrium, the heat in the contiguous bodies muſt undergo a diminution, and the liquor in the thermometer will of courſe deſcend: If the new compound fixes a ſmaller quantity of the matter of heat, the ſurplus will be let looſe, and flow into the contiguous bodies: When the quantity of heat is the ſame in both compounds, (which ſeldom happens), the thermometer will not be at all affected."—Mr Kirwan has lately given nearly the ſame explanation of theſe phænomena, in the Philoſophical Tranſactions. Evaporation muſt be taken into the account: Wherefore, in the laſt caſe ſuppoſed by Profeſſor Bergman, the liquor in the thermometer muſt fall a little. Mr Kirwan, if my memory does not fail me, intimates this circumſtance, but does not expreſsly mention it.

Profeſſor Bergman, I think, in more paſſages than one, obſerves, that the great difference of heat in a ſolution of aerated and cauſtic calcareous earth, is a proof that this earth, when it yields its air, fixes a quantity ſtead of crude chalk, let an equal piece, well burned, be uſed: Let the acid be diluted, and, at firſt, a very few bubbles appear, but ſoon fall; beſides, in this caſe, a conſiderable degree of heat is produced, ſomewhat leſs than 100°.

quantity of the matter of heat; but he who reflects how much of this active fluid muſt be abſorbed by the aerial acid, as it paſſes from its ſolid to its fluid form, will eaſily be perſuaded that this conſideration will explain much of the difference. The ſpecific fire in the compound of nitrous acid and calcareous earth is, doubtleſs, in both caſes equal.

Thoſe who are acquainted with the uſual order obſerved in printing books, know that prefaces, preliminary diſſertations, &c. paſs through the preſs laſt. This circumſtance obliges me to place here an obſervation which refers to page 48. I have there ventured to reject both the author's and the French annotator's hypotheſes reſpecting lime too much burned, and to offer another explanation. Since that note was written, the third volume of the Opuſcula has fallen into my hands, in which I have found that the author himſelf has explained this phænomenon from the very ſame ſuppoſition.—"It is moſt probable," ſays he, "that a ſtrong heat, ſuddenly applied, and long continued, occaſions a kind of fuſion of many particles lying on the ſurface, *moleculæ—fuſionis fere more in ambitu coaleſcere incipiant*, &c." The reader may now ſafely refuſe to admit the author's firſt ſuppoſition, ſince more mature conſideration has induced him to reject it himſelf. B.—But it is now certain that this ſemi-vitrification was owing to the admixture of argillaceous earth, which is very often contained in lime-ſtone.

If the acid be ſufficiently concentrated (but not too much) at firſt, not only ſmall, but even large and numerous bubbles ariſe, which, however, ſoon die away, and all viſible motion ſtops, both in the calcareous maſs and in the acid liquor. In this caſe, however, a very intenſe degree of heat is generated, which, if the piece be large, exceeds 100°.

From theſe phænomena, attentively conſidered, an explanation will eaſily and naturally be deduced. In the latter caſe, for inſtance, ſo much heat is produced, that the watery parts in contact with the burned chalk boil for ſome moments; but when the acid is diluted, only a few air-bubbles, which occupied the pores of the ſpongy maſs, are diſcharged by the expanſive power of the heat. In both, however, the motion is ſoon at an end. But, with the crude chalk, the motion continues until the chalk is totally diſſolved: This motion is called efferveſcence, and muſt carefully be diſtinguiſhed from ebullition.

(B) *A cauſe, any how indicated by phænomena, may for a while be aſſumed as true; and from it may be deduced the neceſſary conſequences, which, being ſeparately examined by ſuitable experiments, either confirm or overturn the poſition.*

This method has been often uſed to advantage in mathematics, and ought to be applied in natural philoſophy, as a teſt for the examination of various hypotheſes and conjectures; and we muſt confeſs, that a poſition, all the legitimate conſequences of which are confirmed by experiment, may properly be admitted as true. In this caſe we have a problem indeterminate, of which the unknown quantities are ſought by experiment.

(c) *Beſides, the cauſe ſhould, if poſſible, ſo be compared with the effect, that the exact relation may be diſcovered, even as to quantity.*

By this it will appear whether the cauſe alone be adequate to the effect, or whether it has been aſſiſted. An inſtance of this kind occurs in the conſideration of agriculture, where a queſtion ariſes concerning the uſe of water in vegetation.

Finally, *I aim at giving denominations to things as agreeable to truth as poſſible.*

I am not ignorant that words, like money, poſſeſs an ideal value, and that great danger of confuſion may be apprehended from a change of names; in the mean time, it cannot be denied that chemiſtry, like the other ſciences, was formerly filled with improper names. In different branches of knowledge, we ſee thoſe matters long ſince reformed: Why then ſhould chemiſtry, which examines the real nature of things, ſtill adopt vague names, which ſuggeſt falſe ideas, and favour ſtrongly of ignorance and impoſition? Beſides, there is no doubt but that many corrections may be made without any inconvenience:

convenience :—If, inſtead of oil of vitriol, and ſpirit of vitriol, we uſed the terms *concentrated vitriolic acid*, and *diluted vitriolic acid*, I think that no one would be thereby either confounded or miſled.

But, in deſcribing new ſubſtances, it is neceſſary that names ſhould be conformable to the nature of the ſubſtances. Thus, inſtead of *fixed air*, I uſe aerial acid, becauſe that fluid is in its nature acid, and not only poſſeſſes the ſubtleneſs and elaſticity of air, but either contains pure air, or ſome of its conſtituent principles; for the pureſt air that can be got, on the acceſſion of phlogiſton produced this fluid, (the aerial acid); I could not therefore find out a name better adapted. Some think that this ſubtile acid is the ſame as phlogiſticated vitriolic acid; but whoever has ſeen and compared the two, cannot ſeriouſly defend that opinion.

Let me have permiſſion to mention here an obſervation, which ſeems to indicate the preſence of phlogiſton in the aerial acid :—Pure vitriolic acid cannot be reſolved into a permanently elaſtic fluid; but, on the addition of phlogiſton, an aerial fluid is generated, (totally different from the aerial acid), which is not condenſed by cold, unleſs it touch water (*b*). The ſame is to

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(*b*) We have now much ſtronger and more direct proofs of this hypotheſis; and the experience of every day to be ſaid of the nitrous acid; but the marine acid by itſelf is reſolvable into an aerial fluid. Now, as this laſt acid contains phlogiſton as a proximate principle, as is demonſtrated by analytic and ſynthetic experiments, it hence ſeems to follow, that the aerial acid contains the principle of inflammability: I ſay, *ſeems* to follow, for all things which are like truth, are not therefore true.

Theſe few reflections it was proper to premiſe. Let the ſkilful and impartial determine with what ſucceſs I have ſought for truth in the following

day ſeems to add to the number. I ſhall not conſider them here; the laſt Eſſay in the third volume will afford a more favourable opportunity. I have in contemplation ſome experiments calculated to elucidate the queſtion: If the reſults ſhall furniſh me with any information, I will there lay it before the public. In the mean time, experimental philoſophers would be well employed in analyſing this acid: The ſolution of few problems will throw ſo much light upon the theory of chemiſtry. If the aerial acid ſhall be found to conſiſt of dephlogiſticated air and phlogiſton, Mr Scheele's doctrine of heat muſt fall to the ground; if not, it will be difficult, in the preſent ſtate of chemical knowledge, to find arguments ſufficient to overthrow it. B.—Mr Scheele's doctrine is now univerſally abandoned. The compoſition of fixed air, too, is become very problematical, ſince it has been diſcovered that water conſiſts of vital and inflammable air, and ſince the exiſtence of phlogiſton has been rendered ſo doubtful.

following eſſays, and whether, as I endeavoured to avoid one rock, I have not ſplit upon another.

Moſt of the eſſays contained in this firſt volume have already been publiſhed ſeparately; but, as the copies were ſoon diſperſed, and, moreover, as ſome were written in Swediſh, ſome in Latin, and others in French, I have undertaken, at the inſtance of my friends, and more eſpecially ſuch as are foreigners, to collect them, and tranſlate into the common language of the learned, thoſe which were written in other languages. I have not diſpoſed them in the order of the time in which they were printed; but I have rather endeavoured that the preceding ſhould illuſtrate thoſe which follow. I have, however, mentioned in a note the time of the firſt publication of each eſſay.

In the firſt volume I have inſerted thoſe eſſays which relate to ſalts; in the ſecond, thoſe which refer to mineralogy and metallurgy ſhall be comprized; the third ſhall contain the doctrine of attractions, together with the analyſis of ſome organized bodies; the fourth, various matters relative to natural philoſophy and natural hiſtory; and in the following I will publiſh, if God grant me life and ſtrength, other chemical eſſays.

I ſhall be ſatisfied if the following experiments, which were inſtituted with all the accuracy and fidelity that circumſtances would permit, ſhall not be diſpleaſing to thoſe who, with me, ſeriouſly ſeek for truth. Of others, I neither deſire the praiſe, nor fear the cenſure. I ſhall not be ſurpriſed if it ſhall appear that I have committed miſtakes; but I wiſh they may be corrected as ſoon as poſſible. I myſelf will add, to the following volumes, whatever corrections or additions more accurate obſervation ſhall ſuggeſt to me. Thoſe who ſhall attempt to obſcure what is true, will find to their diſgrace, that it will ſhine with greater luſtre. Some things which, in one place, are barely mentioned, without any proofs being adduced, are fully proved elſewhere; for I have been anxious to advance nothing raſhly. I therefore intreat thoſe who ſhall examine my aſſertions, not to reject them haſtily, but to conſider the foundation on which they reſt.

BIBLIOTHECA BODLEIANA

## OF THE

# AERIAL ACID.

ABOUT the year 1770, I communicated my ideas concerning the nature and properties of that elaſtic fluid, which, under the title of Fixed Air, exerciſes the ſagacity and induſtry of the philoſophers and chymiſts of the preſent age, to my foreign correſpondents; among whom it is ſufficient to name the celebrated Dr Prieſtly, who not only mentions my opinion in the Philoſophical Tranſactions for the year 1772, but, in a new edition of his excellent Obſervations on Air, has confirmed it by ſeveral fine experiments. The Royal Academy of Sciences at Stockholm have, it is true, inſerted in their Tranſactions for the year 1773, a ſhort treatiſe of mine upon that ſubject. However, as the doctrine contained in it deſerves the moſt accurate examination, and the moſt minute and attentive conſideration, I here republiſh it, confirmed by experiments and obſervations.

## § 1. *What is to be underſtood by the term "Fixed Air."*

For the purpoſe of avoiding ambiguity, it is neceſſary to begin by explaining certain terms. The term "Fixed Air" has been uſed in two acceptations, one more extenſive, the other more limited; in the former it is taken for every elaſtic fluid ſet at liberty during the decompoſition of bodies, by whatever means it is extricated, and whatever be its nature. Theſe fluids, however, are far from being all of the ſame kind; for ſome are very ſuſceptible of inflammation, others inſtantly extinguiſh fire. The reſt differ not a little from each other; but all agree in this, that although very like to common air in many properties, yet they appear to have exiſted as it were fixed in bodies, and deprived of their elaſticity, which they do not recover until the inſtant of their extrication: hence they have generally been diſtinguiſhed from common air by the epithet *fixed*. If this denomination muſt be retained, I do not deny but that the general ſignification above explained agrees perfectly well with it; but the other more reſtricted ſenſe has for ſome time obtained; and as it is in general uſe, I am under the neceſſity of adopting it in the following Treatiſe, denoting by it only that ſpecies of air which is found in alkaline earths and ſalts, extricable by fire or acids, and which iſſues in great quantities from many vegetables during fermentation. This, when properly depurated, poſſeſſes always the ſame qualities, and, as it evidently exhibits the properties of an acid, I call it (conformably to its nature) the Aerial or Atmoſphæric Acid, the reaſon of which denomination will hereafter appear, particularly in § XXII. and XXIII.

That ſpecies of air which ſuddenly deſtroys animals, and is entirely unfit for reſpiration, is called Mephitic Air, ſuch as is found in the cavern near Naples, called Grotto del Cane, and in many others. This pernicious quality is common to moſt elaſtic fluids which have been fixed in bodies; ſo that this denomination is nearly the ſame with that of *Fixed Air*, taken in the more extenſive ſenſe.

## § II. *How pure Fixed Air is procured.*

There are three different methods of obtaining fixed air :—It may be expelled with effervescence by a ſtronger acid (*a*); it may be expelled by a ſufficient degree of heat; or, finally, it may be extricated by fermentation. We ſhall deſcribe all theſe methods in order.

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(*a*) The author in this place conſiders fixed air as an acid, which may be expelled from the ſubſtances with which it is united, by means of a ſtronger acid; and this extrication of fixed air is attended with an efferveſcence. C.

To the orifice A (Pl. I. fig. 2.) of a glaſs phial A B, let there be cemented, ſo that no air can eſcape, the crooked glaſs tube E F G; let the veſſel be nearly half filled with diſtilled water; let there be added pellucid calcareous ſpar, coarſely powdered, until it almoſt riſes to the ſurface of the water C D, through the funnel O, cemented to the orifice L, and imperfectly cloſed by the glaſs rod P; let concentrated vitriolic acid fall in drop by drop; upon which innumerable bubbles will inſtantly ariſe from the calcareous particles: in the mean time let the orifice G of the tube remain open, until the atmoſphæric air contained in the upper part of the bottle, and in the tube, be entirely expelled by the more ponderous fluid diſcharged (§ XXIV.); let the orifice G then be introduced under the mouth of the veſſel H G, filled with water, and inverted with its mouth beneath the ſurface of the water in the veſſel M N.

This being done, numerous bubbles will riſe into the veſſel H I, which collecting above, by degrees force out the water. When the water is entirely forced out from the veſſel H G, the extremity of the tube is to be removed, the bottle cloſe ſtopped under water (*b*), and the air conveyed

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(*b*) The deſign of paſſing the elaſtic fluid from one veſſel to another, is merely to free it from vitriolic acid, whoſe attraction for water is ſo great, that, during its paſſage, it quits the fixed air, and unites with the water. C.

from it into another veſſel Q R, of a ſize ſomewhat ſmaller: as a portion of the air is abſorbed in its paſſage through the water, the aerial acid thus collected in Q R, will certainly be found pure, unleſs, perhaps, mixed with a ſmall portion of atmoſphæric air, which can ſcarcely have been completely expelled by the fluid extricated during the effervescence. If the vapour ſhould contain any vitriolic acid, this laſt will certainly remain in the water, at leaſt after the ſecond paſſage through it.

If, in place of the vitriolic, the nitrous, muriatic, or any other acid (ſo diluted as not to ſmoak (*c*) ) be applied with proper care, the very ſame kind of air is produced, the ſtrength and quantity of the acid muſt be ſo regulated, that ſcarcely any heat ſhall be generated. I avoid making uſe of chalk, as it almoſt always contains marine acid (*d*).

SECOND

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(*c*) If the ſmoaking, nitrous, or marine acid, be employed, it is obvious, that theſe acids, being in this ſtate extremely volatile, will riſe, in part, along with the fixed air, which conſequently will not be pure. The caution againſt heat is founded on the ſame principle. C.

(*d*) If chalk containing marine acid be employed, the heat which vitriolic acid generates on mixture with water, will volatilize the marine acid, and conſequently render the fixed air impure. C.

Mr Morveau having let fall a few drops of a ſolution of ſilver and mercury in the nitrous acid into diſtilled water in which chalk had been boiled, obſerved, that the former ſolution inſtantly clouded the water; and that by the latter a ſmall quantity of yellow precipitate was produced. I have

repeated

## SECOND METHOD.

Let a retort of green glaſs, not above one inch in diameter, be provided, with a very ſlender neck; let the body of the retort be filled with magneſia alba, and placed in a crucible ſurrounded with gypſum, and the whole apparatus be ſet in a portable furnace contiguous to its ſide, ſo that the neck ſhall not be expoſed to the fire; let a glaſs tube be luted to the neck of the retort very

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repeated the experiment, with the ſame reſult, upon one ſpecimen of chalk; but having boiled another in diſtilled water, I found that neither ſolution of ſilver nor the acid of ſugar deſtroyed the tranſparency of the water. Mr Duhamel has long ſince remarked, that "during the combination of quick-lime with the mineral acids, a quick and penetrating vapour is diſcharged, which precipitates the ſolution of ſilver. This circumſtance, added to its odour, led him to ſuſpect that it was the marine acid." See Lavoiſier's Eſſays.——In order to bring this ſuſpicion of Mr Duhamel to the teſt of experiment, I boiled ſome quick-lime in water; and having precipitated the diſſolved earth by means of fixed air, I filtered the water, and added ſolution of ſilver and acid of ſugar, but the liquor was not rendered turbid by either of theſe teſts. It is natural to ſuppoſe, that the marine acid generally contained in calcareous earth would be volatilized by calcination. That which I employed had been well burned: perhaps Mr Duhamel's had not. If, therefore, this ſuppoſition be admiſſible, his obſervation will coincide with that of Profeſſor Bergman. B.

cloſely, (ſo as not to give exit to the elaſtic fluid), and ſo bended, that the aperture of the veſſel H I, inverted in water, may be hung over the extremity G; let the crucible then be made red hot, and ſuffer the air bubbles to fly off until the common air is diſſipated; then let the air which afterwards comes over be collected in the veſſel H I, as in the former method.

I make uſe of a ſmall retort, both that the maſs contained may eaſily acquire a due degree of heat, and that the quantity of common air lodged in its neck and the tube may be ſmall: I chuſe a glaſs veſſel, as thoſe made of earth have often diſappointed me, by giving paſſage to the elaſtic fluid through chinks ſo ſmall as not always to be diſcovered by the eye. Magneſia, when ſcarcely ignited, emits its fixed air with eaſe; whereas calcareous earth retains it with much greater obſtinacy; ſo that if the latter be employed, a much more vehement fire is neceſſary: I ſurround the body of the retort with gypſum, that it may not flow by the violence of the heat, but, on the contrary, grow more refractory by the cementation, and acquire the properties of Reaumur's porcelain.

## THIRD METHOD.

This method differs from the two former; for here the elaſtic fluid is produced by fermentation. It is nearly immaterial what fermenting mixture we employ; but I generally make uſe of the following:—

In a bottle, of which the capacity is 350 cubic inches, I mix 20 oz. of ſugar, and as much of good yeaſt, with 200 cubic inches of water; in ſix or ſeven hours, and in about 15° (*e*) of heat, the common air is generally expelled; I then adapt the orifice G of the crooked tube to the mouth of the bottle H I, and bubbles immediately riſe. The fermentation goes on equally well, if the tube be at firſt adapted to the neck of the bottle, the acceſs of air not being neceſſary; it is ſufficient that an exit be allowed to the elaſtic fluid, as I have often experienced.

It is neceſſary to take care, in this as well as the former methods, that the tube E F G be not too long, as the difficulty of the proceſs increaſes, in proportion to the quantity of air to be removed: let us ſuppoſe this reſiſtance = R, and the elaſtic force of the fluid generated at one time = E, it is manifeſt, that if R = E there will be no room for expanſion, and conſequently no diſengagement can be effected, either by effervefcence, by fire, or fermentation, as the following experiment may ſerve to ſhew:—

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(*e*) In the Swediſh thermometer, the ſpace between the freezing point and the heat of boiling water is divided into 100 deg.; ſo that 10 of theſe degrees are equal to 18 of Fahrenheit's ſcale. Wherefore, 15° = 27, and 27 + 32 = 59. B.

Prepare a ſtrong bottle, nearly full of water, to which let chalk or cryſtallized alkali be added; let it then be filled with any acid, and quickly and cloſely ſtopped: at firſt, indeed, a few bubbles appear, but this appearance ſoon ceaſes, and the mixture remains clear, even for years, provided no exit is allowed to the elaſtic fluid, and ſuch a portion (*f*) only be ſaturated, that the water can take up its fixed air; but the very ſmalleſt aperture immediately excites a moſt violent effervеſcence.

The air which is collected by the ſecond and third methods may, like that got by the firſt, be waſhed (*g*); and by whichever of theſe methods (though ſo very different) it is obtained, it exhibits exactly the ſame properties.

## § III. *General Properties of Acids.*

Saline ſubſtances are uſually diſtinguiſhed from others by their ſapidity, and ſolubility in water. Thoſe which are ſpecifically called acids, exhibit very

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(*f*) If ſo large a portion of the chalk or alkali be ſaturated, before the veſſel is cloſed, that the water is not able to abſorb the elaſtic fluid extricated by the ſaturation, the veſſel will burſt. It is neceſſary therefore to cloſe the veſſel very ſuddenly, or the experiment will not ſucceed. C.

(*g*) By paſſing it through water from one veſſel into another. C.

very diſtinct characters, peculiar to themſelves, which are now to be enumerated; of theſe the 1ſt, 6th, and 8th, are common to other ſaline bodies, but in a mode and degree very different.

1ſt, They very readily unite with water; 2d, They have an acid taſte; 3d, They change the blue juices of vegetables to red; 4th, They have a very ſtrong affinity with alkaline ſalts, and form with them compounds milder than either of the conſtituent parts, which are frequently diſpoſed to cryſtallize; 5th, They diſſolve ſeveral earths; and alſo, 6th, Some metals; 7th, They precipitate ſubſtances diſſolved in alkalis; and 8th, They frequently attract inflammable matters ſtrongly.

If, then, every one of theſe properties be found to belong to pure fixed air, properly collected and depurated, I hope its acidity will no longer be called in queſtion. We ſhall therefore examine all theſe circumſtances in order.

## § IV. *Aerated Water.*

Let the bottle Q R, filled with the pure elaſtic fluid (§ II.) in a place where the thermometer ſtands but a little above the freezing point, be ſet in a veſſel of water, with its mouth depreſſed, by means of weights, almoſt to the bottom of the veſſel, that the union may be accelerated by the preſſure; and the water will be found to riſe by degrees, ſo that at the end of 8, 10, 12, or more hours, according to the ſize of the bottle, it will be filled with water, for the union will have completely deprived the fixed air of its elaſticity. If after that a portion of the elaſtic fluid be introduced into the bottle, the water will riſe but little, or none at all. In an heat of about 5° (*h*) water will abſorb a quantity of fixed air, ſomewhat more than equal to itſelf in bulk; in 10° (*i*) a quantity ſcarcely equal; and in temperatures ſtill warmer it abſorbs a quantity ſo much the leſs, as the mercury ſtands the higher. The quantity neceſſary to ſaturation can hardly be determined with perfect accuracy, as the water, becoming heavier when ſaturated with the elaſtic fluid, ſinks by degrees to the bottom, and leaves the ſpace it before occupied to the lighter water, as would happen to any other ſaline ſolution.

This union may be effected, and that even in a few minutes, by other methods; for inſtance, if by agitation we encreaſe the number of points of contact.—But of this I treat more at large elſewhere (*k*), therefore have here only mentioned the moſt ſimple method.

The ſpecific gravity of aerated water (to make uſe of a new expreſſion) I found to be to that of diſtilled water, nearly as 10,015 to 10,000, the thermometer ſtanding at 2° (*l*).

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(*h*) 41° of F. B. (*i*) 50° of F. B.

(*k*) Vid. Analyſis Aquarum.

(*l*) 35° or 36° of F. B.

Water, therefore, and that ſubtile vapour of which we are treating, readily unite; but as the latter is very volatile, a great part of it flies off in the open air, and the quicker in proportion to the heat of the maſs; in the mean time, as it diminiſhes, the remainder is retained more obſtinately; ſo that boiling for half an hour is neceſſary, to diſcharge the whole. Congelation ſeparates it readily and completely.

The air-pump, it is true, extracts bubbles from equal quantities of plain water and of aerated water, but a conſiderable difference is obſerved: for when a portion of the aerial acid is thus diſcharged, it may be eaſily diſcovered by the taſte, the water being found to have a vapid, leſs acidulous, and leſs pungent flavour.

## § V. *Fixed Air has an acid Taſte.*

As this air is in form of an elaſtic vapour, it can hardly be taſted by itſelf, at leaſt diſtinctly; but if it be united with water, which is in itſelf void of flavour, being accumulated and rendered leſs volatile by this union, it readily affects the tongue with a weak but agreeable acidity. This is the real ſpirit of the cold mineral waters, which undoubtedly occaſioned them to be called acidulous; and by means of which, together with a due proportion of ſuitable ſalts, we may perfectly imitate the Seltzer, Spa, and Pyrmont waters.

Such artificial waters, I have now been uſing for eight years with ſignal advantage.

It is very remarkable, that water ſo cold as only to exceed the freezing point by a few degrees, though ſaturated with fixed air, gives out ſcarce any ſenſible flavour, but if ſet for a quarter or half an hour in 15° or 20° (*m*), it by degrees evolves its pungent and grateful acidity: nor is it difficult to account for this phænomenon, as it is ſufficiently illuſtrated by the known properties of neutral ſalts, the more cloſely the two principles cohere, the leſs ſapid is the compound; on the contrary, the looſer their connection, the more ſenſible is the effect of the compound on the tongue: now in this caſe, as cold ſtrengthens the union of the water with the air, and heat tends to looſen it, from thence the explanation of the phænomenon is eaſily derived.

But alkaline ſalts not only very quickly deſtroy the pungent flavour, but even make the water totally vapid, which it is not difficult to account for: if any portion of them be cauſtic, that is, not ſaturated with fixed air, (§ VII.) their producing the ſame effect, though in a ſlighter degree, even when they are fully ſaturated with air, ſeems to indicate that they attract fixed air more powerfully than water does, and have even the property of accumulating it, ſo as to be ſuperſaturated; particularly as a few drops of the mineral acids re-

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(*m*) 15° = 59°, and 20° = 68° of F. B.

ſtore the flavour of the water, by attacking the alkaline ſalts, and expelling the elaſtic fluid, which is therefore again abſorbed by the ſurrounding water (n).

## § VI. *Fixed Air acts like a weak Acid.*

The acid nature of fixed air is diſcoverable by other ſigns beſides its taſte. If the water in the bottle Q R be tinged with turnſole to a perfect blue, when fixed air ſufficient to fill about the $\frac{1}{50}$ of the veſſel has paſſed through it, it will be manifeſtly red: a ſaturated tincture of turnſole is ordinarily of a violet colour, but when ſufficiently diluted loſes all the reddiſh tinge, and in that ſtate therefore it is particularly proper for this purpoſe.

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(n) "This accumulation of gas in aerated alkali," obſerves Mr Morveau, "does not coincide with the laws of the cryſtallization of neutral ſalts: perhaps it would be better to ſay, that the union of the water and the ſalt looſens the combination of the latter with the fixed air. There is at leaſt no proof that the reſtoration of the ſavour, on the addition of the acid, is not ſolely owing to the fixed air, which was a conſtituent part of the aerated alkali, and is thus diſengaged, according to Mr Venel's method." The law to which Mr M. alludes is not without exception. Cream of tartar and tartarus tartariſatus, calomel, and corroſive ſublimate, volatile vitriolic acid, and ſulphur, are ſuch obvious inſtances of the union of the ſame principles in different proportions, as ſhould have made him more cautious of pronouncing on the improbability of a ſuperabundant portion of fixed air combining with alkali. On this occaſion it may not be impertinent to remark, after an ingenious teacher of chymiſtry, that there prevails very generally an inaccurate and unphiloſophical way of conceiving and expreſſing ſuch combinations as are mentioned above. Two bodies can hardly be imagined to combine in more than one certain proportion. How, then, it will be aſked, are we to explain theſe inſtances?

In like manner, one part of water ſaturated with fixed air, makes 50 parts of the above tincture diſtinctly red.

This change of colour, however, occaſioned by the fixed air, ſoon diſappears in an open veſſel, particularly if it be expoſed to heat, or the rays of the ſun; a circumſtance which indicates the volatile nature of the acid that produces the change: a ſmall portion of mineral acid, it is true, ſeems to yield a fugitive red, but when accurately examined, a fallacy appears, for the water abounds with the alkaline materials with which the turnſole juice has been prepared; theſe ſeize the mineral acid as ſoon as it is added, and give out their fixed air to the ſurrounding liquor,

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ſtances?—By ſuppoſing that a compound becomes in this reſpect an element, and unites with one of its conſtituent parts, in order to form a new compound. Thus corroſive ſublimate, which is itſelf formed by the union of mercury and another ſalt, unites with mercury to compoſe calomel. In the ſame way we are to conceive of the combinations of vitriolic acid and phlogiſton, and of many others. B.

hence a redneſs is obſerved, which vaniſhes when this air is evaporated.—Let us now ſuppoſe that the alkali contained in the liquor requires m parts of mineral acid for ſaturation, hence $\frac{m}{10}$ parts may be ten times added before the ſaturation is complete, and ſo often a fugitive redneſs will be produced; but after the ſaturation is completed, what is added will either at once produce a permanent red, or gradually change the blue to red; here then, it is obvious that the fugitive red colour is not to be attributed to the mineral acid, but to the fixed air.

Syrup of violets, and ſuch other blue vegetable juices as I have hitherto tried, are not reddened by fixed air; the tincture of turnſole is of all known tinctures moſt eaſily acted upon by acids, therefore the ſlighteſt veſtiges, which cannot by any other means be diſcovered, are by this tincture eaſily detected. Beſides, all acids have by no means equal ſtrength and efficacy: diſtilled vinegar makes ſyrup of violets red, yet is not powerful enough to cauſe any alteration in the colour of the blue paper which is uſed to cover ſugar-loaves; and the colour of indigo does not yield even to the moſt concentrated vitriolic acid. Hence, though the aerial acid alters only tincture of turnſole, no concluſion is to be deduced from this circumſtance againſt its acidity, all we can infer is, that it is weaker than the reſt; on the contrary, we are confirmed in the opinion that its acid properties do not depend upon an extraneous acid; for if that were the caſe, this extraneous acid might be ſo accumulated as to overcome the more permanent blue colours.

It is alſo obſervable, that aerated water, free from every other acid, ſcarcely makes any change in the colour of paper tinged with turnſole, although it makes the tincture diſtinctly red; the reaſon is, partly becauſe a ſufficient quantity of this ſubtile acid cannot come at once in contact with the plane ſurface, and partly becauſe the acid is in the former caſe at liberty to follow its natural tendency to volatilization (*o*).

### § VII. *Aerated vegetable Alkali.*

Let the mouth of the veſſel Q R, filled with fixed air, be immerſed under the ſurface of water nearly ſaturated with pure alkali of tartar, and the lixivium will gradually riſe in the veſſel; when it is at length ſaturated with the elaſtic fluid, let it be poured into a proper veſſel, and ſet by in a dry place for ſome weeks, by that time cryſtals will be ſeen adhering to the ſides and bottom of

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(*o*) The aerial acid being diffuſed over the paper, preſents a much larger ſurface to the contact of air, and is therefore ſooner volatilized, than when, being mixed with the water, the ſurface of the water is the only ſurface of evaporation. C.

the veſſel; ſuch of theſe cryſtals as are regular appear to be quadrangular priſms, the apices conſiſting of two triangular planes, inclined to each other, ſomewhat like the roof of an houſe (*p*). The ſaturation of the ley may be collected from its not imbibing any more fixed air. If the water contains too much alkaline ſalt, cryſtals will be produced even in the bottle. The ſame alkali, diſſolved in water, previouſly ſaturated with air, produces by cryſtallization ſimilar figures; theſe cryſtals neither deliqueſce in moiſt air, nor effloreſce in dry, but always retain their tranſparency: they may not improperly be called aerated vegetable alkali, as thoſe ſalts which are ſaturated with vitriolic acid are diſtinguiſhed by the term *vitriolated*, joined to the name of that baſe with which the acid is united.—All ſubſtances ſaturated with fixed air I ſhall call hereafter, for brevity ſake, *aerated*, thereby indicating that they contain that acid which is always preſent in common air (§ XXII. XXIII).

Theſe cryſtals, in a moderate temperature, require for ſolution four times their quantity of water. On calcination they fall to powder, and loſe $\frac{57}{100}$ of their weight, but by a ſlow diſſolution in acids they loſe $\frac{20}{100}$ only; hence it appears that in

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(*p*) As two of the faces are much larger than the others, it would be as exact to define them parallelopipeds, of which the oppoſite ſides have parallel inclinations. Morveau.

100 parts of theſe ſalts, there are 32 of water, 20 of fixed air, and 48 of pure alkali (*q*); hence it alſo appears that 100 parts of pure vegetable alkali require nearly 42 of fixed air to ſaturate them. Complete calcination expels both the fixed air and the water, whereas the acids, if properly applied (§ VIII.), expel the former only. However, in the preſent caſe, it is ſcarcely poſſible to expel all the fixed air by means of fire, unleſs by an exceedingly tedious and troubleſome calcination. The principle on which the corroſive quality of alkaline ſalts depends will be explained in § XI.

The efferveſcence which theſe ſalts raiſe with acids, depends upon expulſion of the particles of fixed air by the ſuperior power of the ſtronger acid, and upon the recovery, at the ſame inſtant, of their elaſticity, which had been either loſt or repreſſed; they muſt therefore riſe to the top by their ſpecific levity, and occaſion a foam on the ſurface.

The taſte of the cryſtals is indeed alkaline, but mild, and not at all acrid; if, however, by means of calcination, or, which is better, by means of quick-lime, they be entirely deprived of fixed air, they are converted into a ſalt highly acrid and corroſive, which is therefore commonly called cauſtic, and very readily deliquiates in the open air; the reaſon is, that it is now left to itſelf, and can

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(*q*) For 48 : 20 = 100 : 41$\frac{2}{3}$, or 42 nearly. C.

fully exerciſe its natural acrimony, which had been repreſſed and weakened by the union of fixed air. The ſame phænomenon takes place with the ſtrongeſt acids, which being ſaturated with an alkaline or earthy baſis, yield mild compound ſalts. Thoſe who attribute cauſticity to phlogiſton ſeem to have forgotten that by means of that ſubſtance the moſt highly concentrated vitriolic acid becomes a ſulphur, totally void of acrimony; that by means of the ſame, the acids of vitriol and nitre are ſo weakened that they may be expelled by concentrated vinegar; and finally, that all acids are dulcified by ſpirit of wine (*r*).

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(*r*) "I am ſenſible of all the force of theſe objections; yet I will obſerve, Firſt, That the vitriolic acid does not exiſt entire in ſulphur, any more than the nitrous acid in nitrous air, or the phoſphoric acid in phoſphorus; that theſe acids do not combine with phlogiſton till they have loſt their air; and that they cannot reſume their acidity till they have recovered their air, which is a conſtituent principle of that ſtate.

"On the other hand, it is no leſs evident, that a ſubſtance can yield thoſe principles only which it contains: now the cauſtic alkalis evidently impart phlogiſton to the precipitates of metallic ſolutions; and hence I have delivered it as my opinion, that alkalis and calcinable earths ought to be placed among thoſe ſubſtances, perhaps more common than is generally ſuppoſed, which cannot be diſengaged from all combination, and which do not loſe one component part, but by the interpoſition of another principle that

The cauſtic alkali, when pure, (by which I underſtand, deprived of its water, and particularly of its fixed air), if expoſed to the atmoſphere, attracts from thence moiſture in ſuch quantity as to be diſſolved; and hence it is called oil of tartar per deliquium. This again is gradually ſaturated with fixed air from the atmoſphere, in conſequence of which it forms cryſtalline vegetations on the ſides of the veſſel.

There are to this day perſons who inſiſt that the vegetable alkali cannot be exhibited in form of cryſtals, notwithſtanding that Profeſſor Bohnius (*s*), of Leipſic, ſo long ago as the end of the laſt century,

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that continues to adhere to them. (See El. de Chémie. Dijon. vol. iii. p. 247.). It will be ſeen in the ſequel of this diſſertation, that the author himſelf inclines to this opinion, ſince he admits a portion of the matter of heat in cauſtic earths and ſalts, of which even ſolution in water cannot deprive them." Morveau.—I think that the conſiderations here alledged do not much invalidate the author's objections to that opinion which attributes cauſticity to phlogiſton. Cauſticity may perhaps be defined—that tendency to combination which matter in general poſſeſſes, exerted on the living and ſenſible body. Thus the cauſticity of acids ſeems to be in proportion to their power of combination, and that of neutral ſalts inverſely, as the adheſion of the acid to its baſis. But I beg leave to refer the reader to the article "Cauſticity," in the new edition of Mr Macquer's Dictionary, where he will find the ſubject diſcuſſed with the uſual addreſs of that elegant and perſpicuous writer. B.

(*s*) See Bohnius, Diſſ. Phyſico Chym. ann. 1696, p. 381.

century, had demonſtrated the contrary; but his method had been ſo long unknown, that it was lately offered to the public as a new diſcovery (*t*).

Although the vegetable alkali attracts fixed air very powerfully, yet it is difficult to obtain a complete ſaturation; for in proportion as the number of cauſtic particles is diminiſhed, they are the more widely diffuſed through the fluid maſs; hence it follows that they more faintly attract, and more difficultly meet with the elaſtic fluid, a circumſtance which occurs in almoſt every ſaturation. During cryſtallization ſome particles ſtill remaining cauſtic, ſully the water of the cryſtals, as is ſeen from the colour of the precipitate of corroſive ſublimate which this alkali produces. Thus pure fixed alkali precipitates a ferrugineous mercurial calx, but when fully ſaturated with fixed air, it precipitates a white one. The vegetable alkali, perfectly cryſtallized, precipitates a whitiſh calx, ſullied with yellow particles; whereas, if theſe cryſtals be powdered, and expoſed to the air upon bibulous paper for ſome days, they loſe all their cauſticity, and precipitate ſublimate in form of a white powder: this white colour depends upon fixed air adhering to the mercurial calx.—§ XXI. Mercury diſſolved in nitrous acid

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(*t*) Hence we may ſee how far Mr Lavoiſier is miſtaken, when he aſſerts, that the original diſcovery of the cryſtallization of vegetable alkali belongs to Mr Duhamel. B.

produces different appearances, according to the different methods of preparation: thus, if the ſolution be effected in the cold, and with diluted acid, a conſiderable quantity of the phlogiſton remains adherent; whereas, if fire be employed, a great part of it flies off in the red vapours: now the more the diſſolved mercury is impregnated with phlogiſton, the paler is the precipitate made by fixed alkali; and on the contrary, the leſs it is impregnated, the darker is the red colour it yields with cauſtic, and the more ſullied the white one with aerated alkali.

In experiments which require great accuracy, I make uſe of alkali prepared from burned cream of tartar, as this is generally free from the marine acid, which, as well as the vitriolic, is in general mixed with ſalts elixated from vegetable aſhes. All alkalis effervеſce with acids, from which we may in ſome meaſure judge of their general nature; for the moſt part they are actually ſaturated with fixed air, that very ſubtile acid, which nevertheleſs is not powerful enough to prevent them from changing blue vegetable juices green; if however, on the other hand, the acid is ſuperabundant, the alkali which it ſaturates does not prevent it from turning tincture of turnſole red, as any one may experience in water which is impregnated with fixed air, and at the ſame time holds diſſolved an aerated alkali. But dry alkali of tartar ſeldom contains more than $\frac{23}{100}$ of fixed air, $\frac{5}{100}$ of water, $\frac{2}{100}$ of ſiliceous earth, and $\frac{70}{100}$ of pure alkali, of which $\frac{15}{100}$ would be in a ſtate perfectly cauſtic if the $\frac{23}{100}$ of fixed air were abſorbed by $\frac{55}{100}$ of the pure alkali, which it is ſufficient to ſaturate, but as it is equally diſtributed through the whole, each particle wants $\frac{9}{100}$ (*v*) of its weight; which deficiency, for the reaſons lately ſtated, will be made up but (*u*) ſlowly, and with difficulty, even in the open air.

## § VIII. *Aerated mineral Alkali.*

Fixed mineral alkali, which, when obtained from marine plants, is commonly called ſal ſodæ, is uſually found ſo much loaded with fixed air, that without any further accumulation it naturally forms cryſtals with ten, or rather eight ſides, of which oppoſite apices are for the moſt part truncated

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(*v*) '23 of fixed air are ſufficient to ſaturate '55 of pure fixed alkali; for (ſee p. 18.) $100 : 42 = 55 : 23$ nearly. I am inclined to think, that into the calculation of the deficiency of weight a typographical error has crept; for this deficiency, which Mr Bergman ſays will be recovered in the open air, can, I apprehend, amount to no more than '0, '06; for, if '23 ſaturate 55 parts, '70 will be ſaturated by $29\frac{3}{11}$, for $55 : 23 = 70 : 29\frac{3}{11}$, and $0{,}29 - 0{,}23 = 0{,}06$; and therefore I conceive the deficiency to be only $\frac{6}{100}$. C.

(*u*) Becauſe all the particles are partly ſaturated, and therefore attract the ſaturating matter with leſs rapidity and force. C.

cated (fig. 6.); and if it be rendered cauſtic by quick-lime, it may again, like the vegetable alkali, be ſaturated with fixed air, § VII.

100 parts of the freſh cryſtals contain of fixed air 16, water 64, and pure alkali 20, ſo that 100 parts of the pure alkali require, to ſaturate them, 80 parts of fixed air (*w*): this is the more extraordinary, as it is certain, that an equal weight of the vegetable alkali, though (*x*) ſtronger, requires no more than 42; but ſuch is in general the nature of ſimple ſalts, that the ſtronger they are, the more eaſily are they ſaturated (*y*). The truth of this chymical paradox may be ſhewn in the following manner:—Let two bottles be provided, the larger containing a given quantity of alkaline ſalt

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(*w*) According to Mr Lavoiſier, the quintal of cryſtals of ſoda contains 63 lb. 10 oz. of water, 15 lb. 15 oz. of elaſtic fluid, and 20 lb. 7 oz. of ſaline matter. This analyſis coincides nearly with that of the author: but Mr Kirwan (Phil. Tranſ. vol. lxxii.) departs widely from both. According to him, in 100 grs. of cryſtallized foſſil alkali, there are 35 of alkali, 20 of fixed air, and 45 of water. Mr Kirwan thinks that the difference is owing to the two former chemiſts having uſed ſoda recently cryſtallized. B.

(*x*) By ſtronger we are to underſtand poſſeſſing the power of diſlodging other alkalis from acids. C.

(*y*) This ingenious artifice affords a very eaſy method of aſcertaining the quantity of fixed air expelled from an alkali by means of acids, together with the quantity of acid neceſſary to ſaturate that alkali. C.

ſalt diſſolved in water; and let the weight of the ſolution, the bottle, and the ſtopple, taken together $= A$; let the weight of the leſſer, containing ſome ſpecies of acid, $= B$; from the leſſer bottle pour into the greater a quantity of acid, and ſtop both ſlightly; the effervefcence being over, let more acid be poured in, and again ſtop the bottles, and ſo on until the ſaturation is complete; then let the weight of the greater $= a$, that of the leſſer $= b$: ſince then $B - b$ has been added to the greater bottle, the decrement of the leſſer muſt equal the increment of the larger; that is, $B - b = a - A$; but this can never happen, unleſs the alkali be perfectly cauſtic, otherwiſe we ſhall always have $B - b \geq a - A$; and their difference $B - b - a + A$, indicates the weight of the fixed air expelled. The effervefcence ſhould be conducted gently, without heat, and in a bottle of proper ſize, leſt ſome watry vapour ſhould fly off with the fixed air, and render the concluſion erroneous.

Let the ſolution in the larger bottle be evaporated to dryneſs, and the reſiduum be gently ignited, in order to expel the water of cryſtallization, and the ſuperfluous acid, if any there be. Let it then be weighed, and from the increment of weight in the given alkaline ſalt, and the weight of the fixed air expelled, we diſcover what quantity of acid is ſufficient to ſaturate the fixed alkali, when freed from water and fixed air; by this method I diſcovered that one hundred parts of pure mineral alkali require, to ſaturate them,

| | Parts. |
|---|---|
| of vitriolic acid | 177 |
| — nitrous | 135½ |
| — marine | 125 |
| — atmoſphæric | 80 |

and that one hundred parts of pure vegetable alkali require, for ſaturation,

| | Parts. |
|---|---|
| of vitriolic acid | 78½ |
| — nitrous | 64 |
| — marine | 51½ |
| — atmoſphæric | 42 |

The quantities of fixed air before aſſigned to the mineral and vegetable alkalis agree preciſely with this table.

What has been already affirmed of alkalis holds good of acids, deprived of their ſuperfluous water: Thus 100 parts of vitriolic acid require

| | Parts. |
|---|---|
| of pure vegetable alkali | 127½ |
| — mineral | 56½ |
| — volatile | 42 |

Cryſtallized mineral alkali, in a dry air, loſes its water, together with its tranſparency, and breaks down into a powder; it diſſolves in a moderate heat in about twice its weight of water: beſides, many properties of the vegetable alkali (mentioned in § VII.) belong to the mineral. The reaſon why it cannot, like the vegetable alkali, precipitate corroſive ſublimate in a white powder, ſhall be explained in § XXI.

## § IX. *Aerated volatile Alkali.*

To obtain the volatile alkali regularly cryſtallized, I choſe that which, being obtained from ſal ammoniac by means of chalk, and a due degree of heat, is ſaturated with fixed air; I then ſaturated water with it in a cloſed bottle, and finally expoſed it gradually to intenſe cold; notwithſtanding which, I could not obtain figures perfectly regular—they ſeemed indeed ſomewhat octaedral, with four truncated angles.—See fig. 7. which exhibits the upper ſurface.

The cauſtic volatile alkali, prepared with quicklime, attracts water very vehemently; it is therefore always fluid, very penetrating, and exceeding volatile: by the method deſcribed § VII. it is eaſily rendered mild, and is to a certain degree fixed, and diſpoſed to cryſtallize.

This alkali is weaker than the fixed; and therefore, according to the rule above mentioned, it ſhould require a greater quantity of fixed air to ſaturate it: And experiments confirm the truth of this; for 100 parts of this alkali, when pure, take up near 105 of the aerial acid; and hence alſo it occaſions a more violent effervеſcence with acids —100 parts of concrete volatile alkali uſually contain 12 of water, 45 of fixed air, and 43 of pure alkali.

## § x. *Aerated Terra Ponderoſa.*

That baſis which, ſaturated with vitriolic acid, forms the ſpathum ponderoſum (the marmor metallicum of Cronſtedt, § XVII. XIX.) bears a ſtrong reſemblance to calcareous earth; but as it differs in many particulars, it is neceſſary to make a diſtinction, until new experiments throw more light on the ſubject. The effervеſcence which this ſubſtance occaſions with acids manifeſtly indicates the preſence of fixed air: that I might be more intimately acquainted with this combination, I expelled the fixed air by burning; poured water on the reſiduum, ſhook it, and then filtered it—after it had ſtood a few hours in the open air, I ſaw the ſurface ſlowly covered with a cream, and all that was diſſolved in the water ſeparated by degrees, in the very ſame manner as happens with lime-water. This pellicle effervеſces with acids; hence we may certainly conclude, that the principle which had been expelled by the fire is now reſtored:

red: by a ſufficient degree of heat, 0,35 of the weight are loſt, and the bottom of the veſſel acquires a bluiſh colour; but by ſlow ſolution in acids, not more than 0,07 are loſt: hence it appears, that one hundred parts contain 7 of fixed air, 28 of water, and 65 of pure terra ponderoſa. Water can take up about $\frac{1}{900}$ of its own weight of this earth in its pure ſtate, and when ſaturated with it precipitates corroſive ſublimate in the form of a yellow powder: it blackens merc. dulcis, and changes the colour of vegetable extracts, in the ſame manner as lime-water does. It is alſo to be obſerved, that this earth acquires ſolubility in water more eaſily, if it be ſeparated from the nitrous acid by fire, than it does by being calcined alone. Although this earth, ſaturated with fixed air, will not enter into an union with common water, yet it diſſolves in water impregnated with that ſubtile menſtruum; for water in that ſtate takes up $\frac{1}{1550}$ of its weight, and even much more, if the earth be reduced to a powder as fine as that of a precipitate: this ſolution changes the red colour of paper tinged with Brazil wood, to a blue; it heightens the colour of paper ſlightly tinged with turnſole; but when the menſtruum is ſuperabundant, it reddens the tincture; it ſcarcely changes paper ſtained yellow by turmeric root: in the open air, the ſuperabundant menſtruum gradually flying off, a cruſt is formed of the ſame kind as that occaſioned in the former ſolution,

lution, by the ſame menſtruum being attracted to ſaturation from the atmoſphere (*z*).

## § XI.

Experiments ſhow that the tranſparent calcareous ſpar, when expoſed to a ſufficient degree of heat, loſes 0,45 of its weight, together with the property of effervefcing with acids, at the ſame time that it acquires acrimony and ſolubility in water:

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(*z*) "Ponderous earth," ſays M. Morveau, "is hitherto but imperfectly known to the French chemiſts. Mr Monnet alone has paid attention to it: he found that the ponderous ſpar is far leſs fuſible than gypſum; that the earthy baſis forms, with the mineral acids, ſalts very different from thoſe produced by the combination of the ſame acids with calcareous earth."—He differs widely from Sir T. Bergman on a point of ſome conſequence; for he contends for the exiſtence of ſulphur completely formed in the ponderous ſpar; he aſſerts, that he has obtained liver of ſulphur, by treating it alone with alkali in cloſe veſſels; he conſequently conſiders it as a true earthy cryſtallizable liver of ſulphur. On communicating to Sir T. Bergman this experiment and deduction of Mr Monnet, that chemiſt returned for anſwer, That he could not but allow that the ponderous ſpar may ſometimes contain ſulphur; but he conſiders the ſulphur as an extraneous ſubſtance; in confirmation of which he obſerves, that it is only preſent by accident, and that the ponderous ſpar may be re-produced by ſyntheſis, poſſeſſed of all its eſſential properties, viz. by combining vitriolic acid and ponderous earth. This anſwer ſeems deciſive. B.

Pure vegetable alkali is very deliqueſcent, and vitriolic acid retains water with ſuch force, that it cannot be exhibited in a ſeparate ſtate by any means yet known; yet if theſe two be combined to the point of ſaturation, a neutral ſalt is produced, one part of which, in a moderate heat, requires 16 of water to diſſolve it. This is one notable example, and upon inquiry hundreds more will occur.

We know that vitriolated vegetable alkali, gypſum, and other ſalts difficultly ſoluble, are more eaſily taken up by water, if it be acuated by an acid. May not aerated lime, therefore, be acted upon in the ſame way by ſuperabundant fixed air? at leaſt, if we admit fixed air to be an acid, we ſhould expect ſuch an effect; and upon experiment this appears to be the fact. Let a ſmall portion of lime-water be dropped into water impregnated with fixed air, ſlight clouds are immediately formed, occaſioned by the ſaturation of the lime by the fixed air: theſe clouds, however, diſappear upon gently ſhaking the veſſel, the lime being again diſſolved by the ſuperabundant fixed air. Put into a bottle, filled with aerated water, tranſparent calcareous ſpar, reduced to an exceedingly fine powder; let this bottle be kept well corked in a cool place for ſome days, and a part of the ſpar will be found diſſolved: this ſolution, filtered through paper, by its ſuperabundant fixed air reddens the tincture of turnſole (lime-water heightens its blue colour); it ſcarcely ſtains blue a paper tinged red by Braſil wood (lime water occaſions a deep blue colour); it does not change the yellow colour of turmeric (lime-water makes it ferruginous); in the open air it forms a cream upon the ſurface, as it is there the ſuperabundant menſtruum firſt flies off (whereas the cream of lime is to be aſcribed to the attraction of fixed air from the atmoſphere); finally, by gentle evaporation, it depoſits an aerated lime, of about $\frac{1}{1500}$, its own weight, which to the eye, aſſiſted by a glaſs, frequently exhibits the ſpathaceous figure (*a*).

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(*a*) M. de Sauſſure has a curious obſervation relative to this ſubject:—he was analyſing a ſulphureous ſpring in the neighbourhood of Geneva. "A lucky accident," ſays he, "preſented me with a new and curious obſervation upon the calcareous earth held in ſolution by this water. I had been trying to ſeparate by the filter the ſulphur, which in the courſe of a few hours precipitates ſpontaneouſly, and renders the water turbid. I afterwards put that which had paſſed through the filter, and was rendered limpid, into a large bottle which had a ground ſtopple. It had remained quite full for a year in the ſame place of my ſtudy, when I wanted it for ſome other purpoſe; but before I threw away the water, I was deſirous of ſeeing whether it had undergone any change. At the bottom I perceived a ſpecies of conferva of a green colour. In order to inſpect this plant more minutely, I half emptied the bottle, and then ſhook it, in order to diſengage the plant; which, notwithſtanding, continued firmly attached to the bottle; but

It may perhaps be ſaid, that it is in the fire the lime acquires its ſaline properties; many are ſtill of that opinion; and it is certain, that this theſis may be ſo explained as not to contradict the ſyntheſis and analyſis above deſcribed: for, ſay they, the whole difference between crude lime and

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in the mean time I perceived a great number of white, ſhining, oblong, and narrow laminæ, floating in the water, which drew all my attention. Having collected them carefully, I found that the longeſt were about half an inch in length, and $\frac{1}{24}$ in breadth, and of the thickneſs of a ſheet of paper. The microſcope ſhewed them to be formed by the junction of ſeveral tranſparent cryſtals, of which the prominent ſummits had the ſhape of a triangular pyramid, and exactly reſembled the ſpar commonly called *pig's tooth* ſpar. I further found that theſe cryſtals were entirely ſoluble with efferveſcence in the nitrous acid, and that with the vitriolic acid they compoſed ſelenite; ſo that I could not doubt that they were real cryſtals of calcareous ſpar.

" By ſcraping the bottom of the bottle, a concretion like tartar was detached, which I found to be compoſed of ſmall cryſtals of the ſame ſhape and nature as thoſe juſt deſcribed; but the laminæ formed by their junction, inſtead of being ſtraight, were variouſly reticulated.

" It was known before, that earthy cryſtals might be obtained by the evaporation of water, holding chalk in diſſolution by means of fixed air. This intereſting diſcovery belongs to Mr Achard of Berlin; but I believe there is no inſtance on record of ſuch cryſtals formed in the water without the aid of evaporation. This fact, however trivial in appearance, ſeems to me of great importance with reſpect to the theory of the formation of the mountains in the midſt of the waters." B.

quick lime does not depend upon the preſence or abſence of fixed air and the water of cryſtallization; for the lime receives in the fire the matter of heat (*b*), (the fixed air and water being previouſly expelled), by which the efficacy of its attraction is in ſome degree diminiſhed; by this new union it is that it becomes ſoluble: but the cauſticity is to be explained entirely upon the loſs ſuſtained by means of the fire, as we ſhall ſoon ſee. Terra ponderoſa, and all the alkaline ſalts, in the ſame way receive the matter of heat; and hence we underſtand how, by a double elective attraction, lime, diſſolved in acids, and precipitated by cauſtic fixed alkali, is entirely ſimilar to lime prepared by fire, and ſlacked in water. The heat which new-burnt lime generates with water indicates no more than a looſe adherence of the matter of heat, which is repreſſed, and prevented from producing ſenſible heat, nearly in the ſame way as the properties of acids are rendered latent by their union with alkalis: but upon the acceſs

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(*b*) Numberleſs phænomena, which we cannot here conſider, evince beyond a doubt that heat is the effect of a certain material ſubſtance.—It is ſufficient here to obſerve, that the ſubtile matter of heat occurs in two diſtinct ſtates; either it is at liberty, in which ſtate it pervades all bodies, ſo that all attain the ſame temperature; or it is fixed by attraction, and does not exhibit ſenſible heat, until ſet free by ſome more powerful attraction.

of a ſufficient quantity of water, the matter of heat is immediately ſeparated by means of a ſtronger attraction, and, being thus ſet at liberty, communicates ſenſible heat to the ſuperabundant water (*c*). If the lime be graduallv ſlacked by the moiſture of the ſurrounding atmoſphere, no ſenſible heat is generated: but we muſt take particular notice, that lime, which generates heat with water, is ſcarcely deprived of all its fixed air; for the intimate nucleus, at leaſt, is found ſtill to efferveſce with acids; and if this reſiduum be expelled, the lime becomes as it were dead and inert; and, although ſtill ſoluble in water, it neither ſplits in ſlacking, nor occaſions any heat. It may be here aſked, How it comes, that by the intenſity of the fire the faculty of heating is loſt, while the ſolubility remains?—This is perhaps owing to the vehemence of the fire, to which the greateſt part of the matter of heat, being very volatile, is obliged to yield. The workmen reject lime which is too much burned, as being uſeleſs, as it does not fall into powder, which is neceſſary

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(*c*) Of all this there is neither proof nor probable preſumption. The heat in this caſe proceeds from the water, which, in conſequence of the attraction of the lime, becomes ſolid, and muſt therefore give out that heat or fire which, as we are taught by Dr Black, conſtitutes its liquid ſtate. There is no fact which might lead us to ſuppoſe, that a great quantity of fire is fixed or rendered latent by quick-lime.

for mixing it; whereas lime leſs burned, in the inſtant of ſlacking, breaks into a powder: for in the latter caſe, the greater part of the fixed air being expelled by the burning, the bulk of the lime is indeed much contracted; but it yet remains of a very ſpungy texture:—water poured upon this readily penetrates it, ſets at liberty the hidden particles of heat; and being by that heat reſolved into vapour, breaks the whole maſs to pieces, and reduces it to a fine powder. Lime, as well as terra ponderoſa, and magneſia, and alſo the alkaline ſalts, when cauſtic, even after extinction in water, produce heat on mixture with acids, the reſiduum of the matter of heat, which water alone was unable to expel, being ſet at liberty; but theſe ſubſtances, being cryſtallized, produce no heat with acids (*d*).

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(*d*) "When chalk, cryſtallized vegetable alkali, &c. are diſſolved in concentrated acids, a very conſiderable heat is produced, a phænomenon which naturally ought to appear; becauſe, without attending to the fixed fire, colliſion always produces heat. As the ſum of the ſynchronous colliſions is far leſs conſiderable, when diluted acids are employed, the cold occaſioned by evaporation compenſates, or even ſurpaſſes, the heat produced, as I have proved in the 2d vol. of the Dijon Mem." Morveau.——Having never ſeen the relation of theſe experiments to which M. de M. alludes, and on which his opinion is founded, I cannot well judge concerning its validity: I am, however, ſomewhat inclined to ſuſpect it; for if the heat produced by

All the circumſtances mentioned in this ſection, as well as the preceding, (§ VII.—X.), being conſidered, or, for fuller conviction, being often put to the proof, I doubt very much whether cauſticity can with propriety be derived from any adventitious matter, eſpecially as it may be explained ſimply and plainly by elective attraction, a power to which all bodies on this globe are found to be obedient; for the purer any matter, the more powerful is its effort towards an union with other ſubſtances; ſo that in this ſtate, acting with undiminiſhed force, it ſeizes with the greater vio-

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the colliſions be compenſated or ſurpaſſed by evaporation, when a weak acid is uſed, an effect not very diſſimilar ought to follow, when a more concentrated one is uſed; for in this caſe, the colliſions being more numerous and inſtantaneous, the evaporation, and conſequently the quantity of fire carried off in vapour, ſhould likewiſe be more conſiderable: beſides, it is ſcarce credible that the cold produced in ſome ſolutions can be owing to evaporation, it is ſo intenſe. I am therefore much more inclined to attribute, with Dr Black, the production of cold to the converſion of a quantity of abſolute into latent heat. B.

To this it may be added, that the ſolution is not Morveau's, but Newton's; and that it reſts upon a theory not received by Morveau himſelf, viz. That heat conſiſts in a tremor of the particles of bodies: wherefore the French annotator is neither original nor conſiſtent. The ſolution of the problem is perfectly eaſy upon Dr Black's principles. The combined bodies attract leſs fire than in their ſeparate ſtate; and therefore a quantity of that which was before latent muſt become ſenſible.

lence thoſe ſubſtances with which it has an affinity, and, if powerful enough, diſſolves their former connection: hence it exerts a violent acrimony; but as it is gradually ſaturated, its force becomes weaker, until a full ſaturation taking place, all this corroſive faculty vaniſhes, and can no other way be reſtored, than by expelling the ſaturating matter. The matter of heat rather repreſſes than quickens cauſticity: it, however, repreſſes it but imperfectly; and hence the preſence of cauſticity always indicates a powerful attractive effort, together with the abſence of the ſubſtances for which the cauſtic body poſſeſſes a very violent attraction (*e*).

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(*e*) "The more chymiſtry is improved, the more numerous and cogent will be the proofs of this theory. But I will here add a few remarks to thoſe upon § VII. — 1. as quick lime cannot be deprived of all the fixed matter of heat, it cannot be affirmed that its properties, in this ſtate of combination, belong excluſively to one of its conſtituent parts; 2. it is certain, not only that compounds, quatenus compounds, have their peculiar affinities; but it is beſides certain, that, in ſome caſes, theſe affinities can be exerted only on compounds. Mr Bucquet has obſerved, that quick lime does not ſlack in fixed air, but it may be inſtantly ſlacked in aerated water: which proves, that water is a neceſſary intermede to the union of the gas; 3. the inertneſs of burnt lime ſeems very difficult to be explained. Sir T. Bergman's conjecture appears repugnant to the general law; according to which, every body

It has already been ſaid, that the moſt ſimple figure of aerated lime is that which is called ſpathaceous:

body that cools in any fluid always retains a portion of that fluid, as a cryſtallizing body always retains part of the liquor in which it was diſſolved. I ſhould therefore rather ſuppoſe that the violence of the heat muſt have deſtroyed part of thoſe principles which this earth derives from organized bodies, and which conſtitute it calcareous earth." Morveau.——I am ready to allow that the author's conjecture is not very probable: but the annotator's ſeems alſo very vague and unſatisfactory, more eſpecially if we conſider that there ſtill ſubſiſt doubts concerning the origin of calcareous bodies.—M. Buffon, and therefore, of courſe, the whole herd of French chemiſts and naturaliſts, contend, that they are the product of the accumulated ſpoils of marine ſubſtances. Mr Pallas and M. Sauſſure too, incline to this opinion: but a diſtinguiſhed naturaliſt has of late combated this opinion, with arguments of great apparent weight. "Calcareous matters," ſays M. de Luc, "cannot have derived their characteriſtic properties from the ſpoils of marine animals; 1. becauſe thoſe ſpoils muſt neceſſarily have been leſs abundant during the moſt remote times, and it was during thoſe remote times, that the moſt conſiderable accumulations of calcareous matter were made; 2. becauſe thoſe great accumulations, ſuch as the calcareous Alps, contain a far ſmaller number of marine ſubſtances than many accumulations of a different nature; 3. becauſe calcareous matters have been found among *primordial* ſubſtances, that is to ſay, ſuch as are prior to all thoſe in which the probable effect of known cauſes can be recogniſed." So far M. de Luc.—With reſpect to the change produced on lime by calcination, carried too far, is it abſurd to ſuppoſe that it may thaceous: I have, I imagine, elſewhere ſufficiently explained how from this are formed the granatic, baſaltic, and other figures (f).

## § XII. *Of aerated Magneſia.*

The magneſia which is found in the ſhops, although vulgarly called an earth, is yet of a ſaline nature; for in a moderate heat diſtilled water is capable of diſſolving $\frac{1}{850}$ of its own weight; and analyſis confirms this opinion, as it ſhews that the primary principles of magneſia, are a peculiar kind of earth ſaturated with fixed air and water. Common magneſia, by proper calcination, loſes 0,55 of its weight, but a vehement and long-continued fire diſſipates ſomewhat even of the earthy baſis; by ſlow efferveſcence in acids, only 0,25 are loſt: hence it appears, that 100 parts of magneſia contain about 25 of fixed air, 30 of water,

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may ariſe from ſuch an alteration as bears ſome analogy to an incipient vitrification? But in queſtions of ſo great obſcurity, there are no bounds to the licentiouſneſs of conjecture. B.——The inertneſs of lime is certainly often owing to an imperfect vitrification; and the imperfect vitrification to the impurity of the limeſtone, or to the admixture of clay. But, I believe, there are inſtances of lime ſlacking without that degree of heat which is generally obſerved. I know not if this depends on the ſame cauſe.

(f) Treatiſe on the Formation of Cryſtals.

and 45 of pure magneſia, which appears to be a true earth; at leaſt, although blended with the matter of heat, I have never yet been able to diſſolve it in water. Magneſia fully ſaturated with air, and cryſtallized, in 100 weight, contains 30 lb. of fixed air: the vapour which is expelled either by fire, or acids collected by the methods deſcribed § 11. and examined, exhibits all the marks of fixed air; in this inſtance the collection of the elaſtic vapour expelled by the fire in the bottle (§ 11.) is attended with the leſs trouble, as it is more looſely connected with the magneſia; whereas, it adheres very ſtrongly to lime, ſo as to require a more violent fire: hence, when lime is uſed, it becomes neceſſary to provide a glaſs of proper thickneſs, and very difficult of fuſion, and to ſurround it with powder of burnt bones, or gypſum, to prevent it from being fuſed. In general too, we may remark, that the greater the diameter of the body of the retort, the more difficult will it be to make the neceſſary heat penetrate to the centre; beſides it will be neceſſary to increaſe the force of the fire continually, for if it at any time is remitted, the tube C F E draws up the water; this inconvenience is ſomewhat leſſened by continuing the extremity G of the tube nearly to the bottom H of the veſſel: —I have fitted up common tobacco-pipes for this purpoſe, and found them very convenient.

The greateſt part of the magneſia which is found in the ſhops is prepared by precipitation from Epſom ſalt; but if the alkali made uſe of be well impregnated with air, the precipitation will be ſmall, particularly in a large quantity of water; for the fixed air, expelled from the alkali by the vitriolic acid, attacks the deſerted magneſia, and diſſolves it; but by a boiling heat the ſuperabundant volatile menſtruum is diſſipated, the magneſia is brought to the point of ſaturation, and almoſt all precipitates.

Water well ſaturated with fixed air diſſolves, in a moderate heat, about $\frac{1}{300}$ of its own weight of common magneſia, and double that quantity, if it be as fine as a precipitate. This ſolution turns the tincture of turnſole red, but heightens that of paper ſlightly tinged by it; makes paper tinged with fernambucum blue, but ſcarcely obſcures the yellow colour of turmeric (for reaſons aſſigned below, I do not make uſe of ſyrup of violets); upon the addition of an acid, innumerable bubbles appear: pure fixed alkali precipitates an earth which does not efferveſce with acids, provided the alkali be uſed in quantity ſufficient to take up all the fixed air, if in leſs proportion an efferveſcence takes place. If the alkali uſed be fully ſaturated with fixed air, it has no effect on the ſolution, unleſs the water be inſufficient to hold both diſſolved, in which caſe the magneſia ſeparates. Pure volatile alkali alſo throws down a precipitate, but an efferveſcing one, as it can attract only the ſuperabundant air; with ſolution of corroſive ſublimate it grows milky, and gradually depoſits a ſmall quantity of white powder; afterwards thin blackiſh cryſtals concrete, compoſed of mercurius dulcis, and a calx of mercury partially aerated. The ſmalleſt drop of a ſolution of mercury, made by heat in nitrous acid, occaſions a copious yellowiſh brown precipitate: but the ſame ſolution, made without heat, yields a white powder, which after ſome days grows greyiſh, as in this caſe the metal has loſt but a little of its phlogiſton. Theſe changes may perhaps be aſcribed to a mixture of alkali adhering to the precipitate of corroſive ſublimate, and which cannot be waſhed away: but this ſuſpicion ſoon vaniſhes, for magneſia has the ſame effect, whether it be precipitated by fixed or volatile alkali; and beſides, precipitates occaſioned by volatile alkali, diſappear in a few minutes, while thoſe which depend on magneſia are permanent.

## § XIII. *Aerated Clay.*

Fixed air ſcarcely ever attacks pure clay, that is, the earth of alum dry and compact; yet the precipitation of alum by aerated alkali ſhews that it does not altogether refuſe to unite with it, when ſufficiently fine and comminuted; for the liquor, well filtrated, although clear, after ſtanding a few days in the open air, and in a degree of heat ſufficient to expel the fixed air, grows turbid, and by degrees depoſits a ſmall portion of earth, which had been ſuſpended by the volatile menſtruum (*g*). Common clay, expoſed to violent heat, gives out a quantity of fixed air ſeveral times greater than itſelf in bulk, mixed with a ſmall portion of inflammable air, which comes off by the firſt action of the fire.

We have already compared (§ VIII.) the alkaline ſalts, with reſpect to the quantity which will ſaturate equal parts of the ſame acid; we ſhall here add numbers proportioned to the weights of the different earths diſſolved by the ſame meaſure of marine acid:

| | | | |
|---|---|---|---|
| pure clay, - | 1,0 | | |
| pure magneſia, - | 2,2 | aerated | 5,7 |
| pure lime, - | 3,5 | aerated | 6,0 |
| pure terra ponderoſa, | 8,7 | aerated | 13,5 |

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(*g*) Profeſſor Schreber, in a Collection of which he is the editor, (Naturforſcher, ſt. 15.), deſcribes experiments upon a ſort of lac lunæ, found near Halle, from which it appears to be argillaceous earth, ſaturated with aerial acid, and mixed with a very ſmall quantity of calcareous earth. But there are ſubſtances to which this denomination is given, which certainly contain no clay, as any one may convince himſelf, by examining the lac lunæ that appears upon the face of the baſaltic rock, called Saliſbury Craig, near Edinburgh. And Mr Kirwan ſhould not have repreſented lac lunæ as clay *ſaturated with aerial acid*, (Mineralogy, p. 71. 72.) without annexing ſome caution reſpecting the ambiguity of the appellation.

Here follow the weights of abſorbent earths, which can unite with 100 parts of aerial acid:

| | | |
|---|---|---|
| pure magneſia, - | 150 | (§ XII.) |
| pure lime, - - | 162 | (§ XI.) |
| pure terra ponderoſa, | 926 | (§ X.) |

Therefore the law demonſtrated (§ VIII.) of alkaline ſalts alſo holds good of earths.

Silecious earth eludes the force of fixed air, and all the other acids, except that of the mineral fluor. The more ſimple earths, therefore, being now conſidered with relation to the aerial acid, we go on to the metals.

## § XIV.

As far as I know, fixed air alone, in its elaſtic ſtate, does not diſſolve nor even corrode any metal, unleſs perhaps during calcination; but when united with water it attacks ſome of them. Let iron-filings be put into aerated water, let the bottle (well ſtopped and inverted) be ſet in a cold place, and in twenty-four hours a portion of the iron will be found diſſolved, ſo that the water will ſtrike a purple colour with (*h*) tincture of galls, make ſyrup of violets green, and form, with phlo-

giſticated

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(*b*) I make uſe of ſpirituous tincture, as it is more efficacious than the watery tincture, and can be kept uncorrupted.

giſticated alkali, Pruſſian blue. If this ſolution be expoſed to the open air, the ſurface which firſt loſes the menſtruum exhibits a party-coloured pellicle, compoſed of particles of iron, reduced to ſuch tenuity as to reflect different colours; by degrees all the iron is ſeparated in form of a ſubtile ochre, which amounts to nearly $\frac{1}{10500}$ part of the weight of the water, and when freſh retains ſo much of the principle of inflammability as to obey the magnet, and be ſoluble in the mineral acids: — Cauſtic alkali, whether fixed or volatile, ſeparates this metal from the water, but when fully aerated has no effect.

Water, impregnated with the fixed air expelled by heat from magneſia or calcareous ſpar, or that collected from fermenting ſubſtances, ſcarcely takes up any calcined iron, except at the inſtant of its precipitation, when it is ſcarcely obedient to the magnet; but if the ordinary method of effervеſcence without waſhing be employed, the water is always contaminated with vitriolic acid; moſt commonly, indeed, ſo ſparingly as not to change the colour of ſyrup of violets diſtinctly, though it reddens paper tinged with turnſole, which water loaded with pure fixed air is never able to do (§ VI.); and beſides, a drop or two of ſolution of terra ponderoſa in the nitrous or marine acids, acts as a very certain teſt, and by a ſlow congrumation detects even the ſmalleſt traces of vitriolic acid, which cannot ſo well be diſcovered by any other means yet known. I am the more certain that this mixture is moſt commonly the cauſe of the ſolution of iron calx, as I have often, by adding it, produced this effect, which water fully aerated was unequal to;—during calcination, indeed, the iron ſeems to unite with fixed air, but water can ſcarcely take up that compound.

## § XV. *Aerated Zink.*

Aerated water will diſſolve zinc very copiouſly, either in its metallic ſtate, or calcined by the proceſs deſcribed in the foregoing ſection. The metallic ſolution, expoſed to the open air, ſoon ſhews its ſurface, covered with party-coloured atoms of zinc; whereas, that which contains the calx appears more obſcure, with leſs variety, and leſs reſplendency of colour. The pellicles which earthy and metallic bodies diſſolved by aerated water yield, on expoſure to open air, nearly agree with thoſe which appear upon evaporating ſolutions of other ſalts, as in both inſtances the neceſſary quantity of menſtruum becomes firſt deficient on the ſurface.

Alkali, when perfectly cauſtic, as alſo tincture of galls, and phlogiſticated alkali, precipitate the metal of a yellowiſh aſh colour. Alkalis fully aerated produce no effect; but as thoſe in common uſe poſſeſs ſome degree of cauſticity (§ VII.) they are not entirely inactive.

## § XVI. *Aerated Manganeſe.*

That ſemimetal which is found in the magneſia nigra, or glaſs-makers magneſia, and which ſeems to be diſtinct from all the other ſemimetals hitherto known, I call manganeſe. Aerated water takes up the black calx of this metal, but far more copiouſly the regulus, in ſuch a manner however that it alſo takes up the iron which is mixed with it. If the regulus be employed, the ſolution diffuſes a particular ſmell, not unlike that which proceeds from burned fat; but the precipitate and pellicles are the ſame as above deſcribed, except as to colour, which is generally influenced by the preſence of iron: moreover, phlogiſticated alkali precipitates pure manganeſe of a yellowiſh white, and tincture of galls produces nearly the ſame colour.

## § XVII. *Union of Fixed Air with other Metals attempted.*

The metals above-mentioned are eaſily diſſolved by aerated water; whereas ſome of the others cannot unite with it, except when divided, as in the very inſtant of precipitation; and moſt of them cannot, even by this artifice, be brought to do ſo. The following metals I put into aerated water, and kept them in bottles well ſtopped and inverted, in a cool place, for eight days, at the end of which time I examined them: viz. gold leaf, aurum fulminans, platina, ſilver leaf, mercury, Æthiops mineral prepared without heat, turbeth mineral, granulated lead, calcined copper, granulated copper minium, ceruſſe, leaf tin, calcined tin; as alſo the ſemimetals biſmuth, nickle, arſenic, cobalt, and antimony, both reguline and calcined;—the water of each bottle was filtered through paper into a ſeparate veſſel, and was found ſtill to retain all its fixed air, for it reddened the tincture of turnſole as before; but moſt of them ſhewed no ſigns of ſolution having taken place. The biſmuth indeed, the cobalt, and the antimony, both reguline and calcined, as alſo the regulus of arſenic, in the open air, ſhewed exceeding thin party-coloured pellicles, which could hardly be obſerved; but on the addition of cauſtic alkali, they exhibited ſlight clouds, and produced, with tincture of galls, a violet-coloured precipitate, ſo that I could ſcarcely doubt but theſe phænomena were owing in a great meaſure to an admixture of iron: yet pure cobalt, as well as nickle, gave ſome tokens of being diſſolved, but theſe tokens I hold to be ſtill ambiguous.

I tried gold leaf in another way, but in vain; namely, I put into diſtilled water, along with the leaf, either the calcareous ſpar, or aerated alkali, then by degrees I poured in vitriolic acid, ſo as not to produce a full ſaturation, yet after ſome days I found no ſolution had taken place: once indeed, when I uſed chalk and common water, I ſaw ſome veſtiges of a ſolution; but upon examining more accurately, I found a little marine acid in the chalk, and diſcovered lime diſſolved in nitrous acid in the water, from whence a ſmall portion of aqua regia had been generated. The vitriolic acid itſelf is frequently found to contain a portion of nitrous acid, which is uſually employed to diſcharge its brown colour:—The moſt extreme caution is neceſſary to avoid being deceived by adventitious circumſtances.

But, becauſe the metals were tried in this way in vain, we are not to affirm that they cannot be united with fixed air, for perhaps it might be done, if they were minutely divided by precipitation; I examined this ſuppoſition in the following manner:—To the ſolution of a metal in its proper ſolvent, diluted with a ſufficient quantity of diſtilled water, I added, by degrees, either aerated vegetable alkali, magneſia, or calcareous ſpar; the ſaturation being completed, I kept the bottles cloſed and inverted, in a cold place, for ſome days, and then examined the water after filtration: I avoid making uſe of chalk, which is often mixed with marine acid, and therefore in certain caſes might occaſion confuſion; with crude lime, the ſaturation is obtained very ſlowly, eſpecially if the menſtruum be vitriolic acid, partly becauſe the ſurface, aſſuming a gypſeous nature, defends the internal particles, partly becauſe the laſt portion of the acid can only meet with the chalk at the bottom of the veſſel, unleſs the liquor be frequently ſtirred; while, on the contrary, the magneſia, and eſpecially the alkali, by their ſolubility, are ſpontaneouſly diſperſed through the whole maſs: magneſia, however, is beſt, inaſmuch as, though it diſſolves ſpontaneouſly, yet the ſolution goes on ſo ſlowly, that the water has time to take up the greateſt part of the fixed air, as it is expelled; whereas, when the effervescence is violent, a great number of bubbles riſe to the ſurface, and fly off.

By this method, beſides thoſe metals formerly enumerated, which may be directly diſſolved in aerated water, a ſmall quantity of gold appears to be taken up, but that in ſo ambiguous a manner, that, upon examination, I am ſtill undecided. Gold is precipitated from aqua regia very ſlowly, by magneſia and by lime, and but imperfectly by alkalis, as a part of the precipitate is rediſſolved by the precipitant; ſo that the liquor can ſcarcely be diveſted of its yellow colour. The ſolution of gold, which with tin depoſits a purple powder, does not hold the gold diſſolved by the fixed air alone; for, to occaſion a precipitation, it is neceſſary that there ſhould be preſent a menſtruum ſuch as may be able to take up the tin, which aerial acid cannot do.

I ſubjected platina, ſilver, mercury, lead, an the other metals and ſemimetals, to ſimilar experiments; but the event was the ſame, and I found no certain tokens of ſolution. That ceruſſe ſhould refuſe ſolution by the medium of fixed air, ſurpriſed me, eſpecially as it is itſelf nothing more than an aerated calx of lead, and therefore diſſolves in acids, with effervescence, and the vapour which is expelled poſſeſſes all the properties of fixed air. In this experiment I employed ceruſſe perfectly free from chalk.—In like manner ſilver, mercury, copper, tin, biſmuth, nickle, and the other metallic ſubſtances, diſſolved in acids, and precipitated by aerated alkalis, take up the fixed air, but yet cannot by its means be diſſolved, except that when the acid is ſuperabundant, before the precipitation, a ſmall portion of copper is taken up;—a complete precipitation is with difficulty obtained by lime and magneſia, though uſed in large quantities. The metallic ſalts always redden paper tinged with turnſole, a property which it is extremely difficult to repreſs by means of the above-mentioned earths.

## § XVIII. *Inflammable Matters greedily attract fixed air.*

The common acids frequently attack inflammable bodies with peculiar avidity, as is well known; although the union of an acid with pure phlogiſton (which is commonly called ſulphur) takes place but in few of them—fixed air alſo poſſeſſes this ſame property.—If the bottle Q R, filled with fixed air, be plunged with its mouth under ſpirit of wine, the ſpirit will be found to abſorb, in a temperature of 10°, double its own bulk of fixed air.—Let the ſame experiment be tried with olive oil, and it will be found that it will abſorb an equal, nay ſometimes a greater, bulk than its own; ſo that a ſtratum of oil floating upon water is of little uſe, as it ſcarcely, if at all, retards the abſorption of fixed air. Oil of turpentine abſorbs nearly twice its own bulk, and that in the beginning with ſuch avidity, that in the firſt half hour about a fourth part of the fixed air diſappears. Ether does not diminiſh fixed air, but expands it nearly to a double volume; however, if this vapour be again paſſed through water, it reaſſumes its original quantity and quality, ſo that the extraneous mixture preſent in this caſe cannot effect a permanent change.

Fixed air is not without difficulty combined with pure phlogiſton (yet they appear united in charcoal) (*g*); and perhaps this union may alſo be

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(*g*) "As charcoal neceſſarily contains a portion of earth, it ought, I think, to be conſidered as an hepar, or ſalt of three ingredients; beſides, neither the phlogiſton nor the fixed air are quite pure; the former is in the oily ſtate, and it is probable that the latter is only a conſtituent part of a more compound acid." Morveau.—This (I fear conjectural) be effected by electric ſparks drawn quickly through it, by which means the fixed air is ſo loaded with phlogiſton as to reject an union with water: if the fixed air which olive oil holds united with it be again expelled by fire, and received in a veſſel, it is found either to a certain degree changed, or mixed with heterogeneous matters; for it can now ſuſtain flame, and is almoſt inſoluble in water (*h*).

§ XIX.

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jectural) analyſis of charcoal will not be intitled to much attention, if the reſult ariſing from ſome unpubliſhed experiments made by Dr Prieſtly may be admitted. That indefatigable philoſopher is ſaid to have converted almoſt the whole of a quantity of charcoal into inflammable air, by throwing the focus of a lens upon it. This fine experiment will very much contribute to ſupport the opinion, that inflammable air and phlogiſton are only different modifications of the ſame ſubſtance; an opinion very ingeniouſly maintained by Mr Kirwan in a late vol. of the Phil. Tranſ. B.

But it is now a matter in diſpute, whether charcoal contain any inflammable air at all. Dr Prieſtly could not obtain any without water, which is now known to yield it. This doubt cannot be finally reſolved, till the tottering doctrine of phlogiſton is quite overturned, or replaced *firmo talo*.

(*h*) "If theſe experiments be joined to thoſe related in the Elem. de Chémie. Dijon. vol. i. p. 334. and vol. iii. p. 384. &c. it will be evident that our knowledge of the combinations of fixed air with inflammable ſubſtances, and in particular with oils, is very deficient: it is not, for inſtance, eaſy to comprehend why vegetable alkali cryſtallizes,

## § XIX. *Fixed Air precipitates Bodies diſſolved in pure Alkalis.*

It is a known property of acids, that they precipitate bodies diſſolved in alkalis; and the ſame may be done by fixed air.

Let

lizes, when immerſed in oils, whether eſſential or expreſſed, without altering their ſenſible qualities; why cauſtic alkali reduces them to the ſtate of ſoap, while their rancidity ſeems to ariſe from the loſs of fixed air, ſince it is corrected by the reſtitution of this fluid; and laſtly, why quick lime ſlacks in oils but very ſlowly and imperfectly. The ſolution of theſe problems will certainly lead us to the diſcovery of ſome important truths." Morveau.—The ſolution of the laſt problem would not perhaps be very difficult, if we may aſſume, with Profeſſor Bergman, that in quick lime calcareous earth is united with fixed fire; and with Stahl, that fixed fire is phlogiſton; a liberty, however, for which I would not very ſtrenuouſly contend. As oils are already ſaturated with phlogiſton, they muſt be incapable of taking it from quick lime, and therefore this ſubſtance can only loſe ſuch a portion as can be tranſmitted through the oil into the air. If ſuch an explication of the phænomenon was admiſſible, it would ſeem to follow, that quick lime cannot ſlack in fluids ſaturated with the inflammable principle. *Sed hoc ariolari eſt.*

The reader will not perhaps be diſpleaſed, if I tranſcribe the paſſages referred to by M. de Morveau, eſpecially as they are to be found in a work not very commonly to be met with in this country.

"Oils cannot unite with alkalis, unleſs they be perfectly cauſtic; but if deliqueſcent alkali be poured into oil,

and

Let ſulphur, diſſolved in lime-water, be expoſed to fixed air in the bottle Q R ; immediately the ſolution grows turbid, depoſiting a lime which

efferveſces

and the veſſel remain for ſome time unſhaken, very fine cryſtals, in the ſhape of parallelopipeds with oblique angles, will be formed at the bottom. They form alike in unctuous oil, in eſſential oil of turpentine, and ſtill better in animal oil. Now, as the heavier alkali falls to the bottom of the veſſel, we muſt infer that there is an affinity between the oil and fixed air; whether it furniſhes alone that which is attracted by the alkali, or receives, at the ſurface which is in contact with the atmoſphere, a quantity equal to that which it is obliged to yield to the ſuperior attraction of the alkali.

" As the rancidity of oils is occaſioned by the diſſipation of the fixed air that formed a conſtituent part of them, this alteration may be prevented by reſtoring as much as they have loſt. The Abbè Rozier obſerves, that if a ſpunge, imbibed with a ſoft paſte of alum and abſorbent earth, be kept at the bottom of a veſſel containing oil; as the abſorbent earth has a greater affinity with vitriolic acid than clay, a ſlow decompoſition of the alum is effected, and a new ſalt is formed; but in every ſuch combination a conſiderable quantity of air is extricated, which, as it eſcapes, will mix with the oil, and prevent rancidity: in like manner ranced oils may be recovered by reſtoring the fixed air. M. Sieffert has given a very good proceſs, in which he employs air extricated by fermentation: it conſiſts in mixing with the altered oil $\frac{1}{10}$ of apples, plumbs, or ſtrawberries, &c. reduced into a pulp; in ſetting this mixture in a place where it will ferment, and aſſiſting it with a little honey, provided fermentation ſhould not go on with ſufficient rapidity: the oil, if drawn off after this proceſs is

over,

efferveſces with acids, becauſe pure calcareous earth adheres more readily to fixed air than it does to ſulphur.

Hepar ſulphuris, prepared with fixed alkali, is likewiſe precipitated, but ſomewhat more ſlowly, as the aerated alkali is eaſily retained by the water, therefore in this caſe the ſulphur precipitates alone; beſides if (as is uſually the caſe) more alkali is preſent than is ſufficient to diſſolve the ſulphur, no turbidneſs is occaſioned, until the ſuperabundant alkali is firſt completely ſaturated.

The volatile hepar ſulphuris, which contains ſulphur diſſolved in pure volatile alkali, and is commonly called the ſulphurated ſmoaking ſpirit of bejuin, is very quickly and ſpeedily rendered turbid by fixed air. No alkali, except when cauſtic, can attack ſulphur; and therefore, upon the acceſſion of fixed air, all the alkalis are rendered unfit for retaining it.

Liquor of flints, in the open air, gradually depoſits its ſiliceous earth; a depoſition which is quickly effected, if fixed air be made to float or its ſurface, and that the ſooner, as the alkali i leſs predominant. This is the reaſon why a ſol tion of alkali of tartar, although repeatedly f

ter

over, will be not only reſtored, but improved; ſince naturally acrid may be brought, by this method, alm the mildneſs of oil of olives." Elemens de Ch Dijon. B.

tered, continues for a great length of time gradually to depoſit earthy flocculi; for this alkali contains, intimately mixed with it, flinty particles, which it has acquired either during vegetation or combuſtion.—The calciners of pot-aſhes ſometimes fraudulently add ſand, in order to increaſe the weight; which, during the operation, ſo unites with the aſhes, that the flinty matter, by means of the alkaline ſalts, becomes ſoluble in water along with them.—This flinty matter afterwards gradually ſeparates, in proportion as the alkali is ſaturated with fixed air, with which this latter more willingly unites. Now, as the alkali is kept in a bottle with a narrow neck, and generally ſtopped, it muſt receive the precipitating matter from the atmoſphere very ſlowly.—The ſeparation therefore proceeds very gradually; but if it be diſſolved in a large quantity of water containing fixed air, or if, from the ſolution having been long made, it is ſufficiently loaded with fixed air, the whole earthy matter at once falls to the bottom (*k*).

Soap

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(*k*) Hence we learn what reſpect is due to M. Baumé's opinion, which has been frequently copied into elementary books, concerning the cauſe of this depoſition: according to him, it happens in conſequence of a real decompoſition of the alkali, of which the conſtituent parts are far leſs intimately united than thoſe of the acids. A portion of the nearly pure fire, to which it is indebted for its ſaline properties, Soap is hardly decompoſed by fixed air, partly becauſe the alkali is almoſt always ſuperabundant, partly becauſe this ſubtile acid among all known acids is the weakeſt, and is accordingly required in great quantity; for even of common diſtilled vinegar no ſmall quantity is requiſite to ſeparate the oil from the alkali: the apparent difficulty of this decompoſition is alſo occaſioned by this, that the ſmall oily globules which are gradually ſeparated, being viſcid, cannot eaſily run together in diſtinct drops.

Aerated as well as pure volatile alkali attacks copper; and hence it happens, that neither in the open air, nor by the addition of vitriolic acid, is this ſolution made turbid or precipitated.

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perties, is diſſipated, and a proportional quantity of earth is ſeparated, and falls to the bottom;—this ſalt may be eaſily decompoſed, by driving off the air and fire that are among its conſtituent parts: at the end of theſe operations, the earth and water, the other conſtituent parts, may be collected ſeparately. Chymie Exp. & Raiſonn. tom. i. p. 322.—Of M. Baumé's work, whatever merit the experimental part may poſſeſs, candour muſt allow, that it is too full of idle ſpeculations and groundleſs conjectures; and that the inexperienced reader cannot be put too much on his guard againſt being miſled by ſuch falſe lights. I was deſirous of an opportunity to introduce this caution, and to confirm it by an example, as M. Baumé's Chymiſtry has been ſtrongly recommended to the attention of Engliſh ſtudents by Dr Watſon, in his popular Eſſays. B.

## § XX. *The ſimple elective Attractions of fixed Air.*

We have ſeen, in the foregoing ſections, that fixed air unites with alkaline ſalts, with earths, and metals, after the manner of an acid; it remains now to examine the different degrees of intenſity with which it attracts theſe different matters.—I mixed them in their pure ſtate with aerated ſubſtances, and kept them in diſtilled water, and in bottles which were immediately cloſed, leſt the acceſs of heterogeneous matter ſhould render the concluſion ambiguous; I then accurately obſerved ſuch changes of weight and quality as could be ſubſervient to the end propoſed.

(A) I added aerated terra ponderoſa to pure vegetable alkali; but after a few days neither was the former diminiſhed in weight, nor the acrimony of the latter in the leaſt mitigated. Terra ponderoſa, therefore, retains fixed air with greater force than the vegetable alkali attracts it, which is alſo confirmed by mixing the pure terra ponderoſa with a ſolution of the ſame alkali aerated; for then the terra ponderoſa is increaſed in weight, and becomes mild, and the alkali is rendered cauſtic. If vegetable alkali, perfectly pure, be added to water loaded with pure terra ponderoſa, no precipitation takes place; but if the alkali be aerated, immediately a turbidneſs ariſes, the alkali is rendered cauſtic, and the terra ponderoſa precipitates aerated; but ſince, agreeably to its ſtrength (*l*), terra ponderoſa is ſaturated by a very ſmall portion of fixed air, we muſt determine the quantities to be mixed together (§ VII. VIII. X.);—now 100 parts of aerated vegetable alkali contain as much fixed air as is ſufficient to ſaturate 390 parts of pure terra ponderoſa, if each of the materials be diſengaged (compare alſo B.)

All the circumſtances juſt now mentioned take place when lime is uſed inſtead of terra ponderoſa, except the proportions, which in this caſe are, that 100 parts of aerated alkali cannot, with its fixed air, ſaturate more than 68 parts of pure lime.

Let 263 parts of mineral alkali, newly cryſtallized, and 100 parts of pure vegetable alkali, be diſſolved together in 300 parts of warm water; then let the ſolution evaporate over the fire, in a proper veſſel; and let the pellicles which ſucceſſively appear on the ſurface be taken away, and collected in a cone of filtering paper, ſo as to be freed from the adhering cauſtic liquor; and let this be continued until the pellicles make up from 150 to 200 parts; theſe, upon examination, are found to be the true vegetable alkali aerated; and the remaining lixivium contains the mineral al-

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(*l*) Vid. Sect. VIII.

kali in a cauſtic ſtate: hence we may eaſily form a judgement concerning the ſuperiority of attraction between the vegetable and mineral alkalis.

93 parts of aerated volatile alkali give over their fixed air to 100 parts of pure vegetable alkali, and aſſume a cauſtic nature, but the latter portions are more ſlowly decompoſed.

168 parts of aerated magneſia contain only ſo much fixed air as is ſufficient to ſaturate 100 parts of pure vegetable alkali.

We have already obſerved, that metals diſſolved in water by means of fixed air are precipitated by cauſtic vegetable alkali.

(B) What has been already ſaid of the vegetable alkali holds good with reſpect to the mineral, with relation to terra ponderoſa, lime, volatile alkali, magneſia, and metals, only changing the proportions; but it is in general to be obſerved, that the numbers coming out in any caſe, according to the principles already eſtabliſhed, only indicate accurately how much fixed air is ſufficient to ſaturate the ſubſtance employed, when at liberty; but as the operation proceeds much more eaſily at the beginning than at the latter end, the complete reſolution frequently requires double, triple, or even ſix times the quantity of the decomponent.

(C) Volatile alkali ſurrenders its fixed air, not only to terra ponderoſa, lime, and fixed alkalis, but even to pure magneſia; for this laſt, being added to a ſolution of aerated volatile alkali, requires the power of effervеſcing, and renders the alkali pure.

(D) Aerated terra ponderoſa, ſo far as I have yet been able to obſerve, neither is itſelf changed, nor occaſions any change in lime-water; but when burned and diſſolved in water, it ſomewhat obſcures the tranſparency of the calcareous ſpar added to it; but the difference of the attractive force of theſe bodies is ſo ſmall, that the prevalence of the terra ponderoſa is not yet quite free from doubt.—Magneſia moſt certainly gives out its fixed air to terra ponderoſa.

Terra ponderoſa, diſſolved by ſuperabundant fixed air, is precipitated by all alkalis, by pure lime, and pure magneſia; all which bodies, by abſorbing the ſuperabundant menſtruum, reduce the terra ponderoſa to exact ſaturation, in which ſtate it is indiſſoluble in water, § x.

(E) If aerated magneſia be put into water loaded with pure lime, it ſoftens the acrimony of the lime-water, and a lime, poſſeſſing the property of effervеſcing, is at length found at the bottom, together with pure magneſia. Lime, diſſolved by means of the ſuperabundant fixed air, exhibits the ſame phænomena as the terra ponderoſa in the ſame ſtate; for the menſtruum, when ſuperabundant, adheres more looſely than when it is only ſufficient for ſaturation.

(F) Pure magneſia is not ſoluble in water, ſo far as is yet known; but if it be taken up by means of fixed air, it is precipitated by alkalis, terra ponderoſa, and lime. When they are cauſtic, the precipitate is ſometimes pure, ſometimes aerated, in proportion to the quantity of the precipitant;—for the ſmall portion which can be ſaturated by the ſuperabundant fixed air, reduces the magneſia to a ſtate of ſaturation; ſo that, being rendered indiſſoluble, it falls for the moſt part to the bottom, unleſs the quantity of water be large; and even the pure volatile alkali is able to effect this precipitation (§ XII.), although inferior in attractive power (C). Terra ponderoſa and lime applied in the ſame way, being themſelves ſaturated, fall in like manner to the bottom; but if the firſt-mentioned ſubſtances be added in ſufficient quantity to the magneſia, they not only ſeize the ſuperabundant fixed air, but alſo that which is neceſſary to ſaturate the magneſia, which therefore, in this caſe, is precipitated pure (G). Metallic bodies diſſolved by fixed air (§ XIV.—XVI.) are precipitated by alkalis, or earths when cauſtic. As to zinc, its ſolution, like that of the reſt, grows turbid with pure volatile alkali; but being gently ſhaken, the clouds again diſappear, becauſe the volatile alkali eaſily diſſolves this ſemimetal.

Alkalis fully aerated, as alſo magneſia and lime in the ſame ſtate, do not at all diſturb the metallic ſolutions, when newly made; but if they be expoſed either to the open air or to heat, ſo that part of the fixed air ſhall have flown off, and the remainder adhere but ſlightly, a ſeparation is occaſioned, owing to the ſlight connection which now takes place between the metals and the water.

It is well known that zinc precipitates all the other metals from menſtrua; and that this would, in the preſent inſtance, take place, I have no doubt, provided the quantity of fixed air could be ſo adjuſted as to be ſufficient only to diſſolve one of the metals; but this can hardly be hoped for: ſo long, therefore, as the menſtruum is ſufficient for diſſolving two or more together, neither any ſeparation or precipitation will be obſerved. I have added filings of iron to ſolutions of zinc, both in the ſtate of regulus and of calx; and again, to ſolutions of iron I have added zinc, and after ſome days I have found the metals laſt added partly diſſolved, without any ſeparation of the former. It may therefore be aſked, Why the aerated water does not take up the former to ſaturation, as we find that it can afterwards attack the latter? The following explanation appears to me to be moſt ſatisfactory:—Aerated metals are ſalts extremely difficult of ſolution, ſo that by experience we find that only a very minute portion of them can be taken up by water; water, however, when ſaturated with one ſalt, not only does not refuſe to take up more, but the preſence of many increaſes their mutual ſolubility; which may be illuſtrated by ſeveral examples: thus, when ſaturated with nitre, it will not only take up common ſalt, but, being fully ſaturated with the latter, will again diſſolve more nitre. In the preſent inſtance, this is the leſs wonderful, as we know for certain, that the firſt metal leaves untouched a ſufficient quantity of the menſtruum (fixed air) for the ſolution of the laſter.

If, therefore, a table of affinities is to be drawn up for the metals, we have no reaſon for departing from that which belongs to the other acids;—that, namely, which has zinc firſt, mangancſe next, and laſt iron.

We deduce, therefore, from the preceding experiments, the following table of elective attractions.

### AERIAL ACID.

Pure terra ponderoſa
—— lime
—— fixed vegetable alkali
—— fixed mineral alkali
—— magneſia
—— volatile alkali
zinc
manganeſe
iron.

BIBL. CODR. COLL. OMN. ANIM. OXON.

(H) With reſpect to the acids hitherto known, he aerial appears to be the weakeſt; for it is expelled, not only by vinegar, but by the phlogiſticated acids of nitre and vitriol. In the mean time, however, I have more than once ſeen water loaded with the very pureſt fixed air (which had been extricated by fermentation, fire, or nitrous acid) grow turbid with a ſolution of lead in vinegar; yet, although at other times I had diſpoſed the quantities of the ingredients, and every other circumſtance, in the ſame way, no veſtige of turbidneſs appeared. It is known that boiling vinegar takes up ceruſſe, and expels its fixed air. Perhaps, then, old cryſtals loſe by age a part of the vinegar; perhaps they are decompoſed by abundance of water, ſo that the aerated water can take up the calx of the lead, and with it form a ſalt which altogether rejects water, but is diſſolved again in the vinegar, without any viſible effervescence.—I leave this queſtion undecided, until I can explain the cauſe of diſagreement between theſe experiments: I do not make uſe of the vitriolic acid, as the very ſmalleſt mixture of that acid precipitates acetated lead.

## § XXI.

Pure volatile alkali cannot precipitate either terra ponderoſa, lime, or magneſia, diſſolved in any common acid; but aerated volatile alkali effects ſuch a precipitation very readily: hence, although the former, by many experiments, plainly appears to be the ſtronger, yet ſome perſons, from this circumſtance, (the true reaſon of which they do not underſtand), think it weaker. But the truth is quite otherwiſe; namely, the volatile alkali attracts all acids with much leſs force than lime (I take this inſtance only by way of example); therefore, when that ſalt is pure or alone, no decompoſition takes place; but if it be impregnated with fixed air, then a fourth ſubſtance is added, which attracts the lime, ſo that the calcareous ſalt is acted upon by a double force; one the attraction of the pure alkali, ſoliciting the acid, the other that of the fixed air for the lime; and theſe forces joined together overcome the original adheſion of the lime with the acid.

The ſame is to be ſaid of aerated magneſia, which in like manner decompoſes calcareous ſalts.

Beſides, although pure fixed alkalis can ſeparate acids from many earths, and from metals, it does not follow, that this proceſs may not be performed by a double decompoſition, when the alkalis employed are aerated. Hence that remarkable difference of weight which is often obſerved in precipitating the ſame ſubſtance. Let 100 parts of calcareous ſpar be diſſolved in an acid; theſe, precipitated by cryſtallized fixed alkali, being accurately collected, waſhed, and dried, yield nearly 100 parts again, ſimilar in their nature and properties to crude lime. But if the operation be performed with pure alkali, the precipitate will not be more than 0,55, and agrees in properties with burned and ſlacked lime; and the ſame is true of all ſubſtances which in their natural ſtate abound with fixed air. Metals indeed differ in this reſpect; yet they too gain from aerated precipitants a conſiderable increaſe of weight; for inſtance—mercury $\frac{1}{3}$, iron nearly an equal weight, and ſo on. Silver diſſolved in nitrous acid is more eaſily precipitated by aerated than by cauſtic alkali, and the precipitate is heavier. Theſe acceſſions of weight are to be attributed to the fixed air, which being expelled by the ſtronger acid, adheres to the deſerted metal, and, according to its quantity, alters not only the weight, but ſometimes even the colour. We ſaid before, that pure vegetable alkali precipitates corroſive ſublimate of a ferruginous colour, but when fully aerated of a white (§ VII.): we ſaid alſo, that the mineral alkali can never produce a white calx of mercury (§ VIII.): let us now ſee the reaſon.

Let there be precipitated only ſo much as is united with 100 parts of marine acid, and let the precipitation be made with vegetable alkali, fully aerated; for which purpoſe about 415 are neceſſary; for 100 parts of marine acid require 199 of pure vegetable alkali (§ VIII.); and theſe 199 can receive 84 of fixed air, and 132 of water (§ VII.). But if the mineral alkali be uſed, 100 parts of marine acid require only 80 parts of alkali; which in cryſtallization receive 64 parts of fixed air, and

256

256 of water. Since, therefore, the mercurial calx, in this inſtance, requires 84 parts of fixed air to be made white, and the mineral alkali ſufficient for the precipitation can ſupply only 64, it appears plainly why this alkali cannot throw down a white precipitate (*m*).

It is very probable that even the calxes of the baſer metals, although prepared by fire, are not altogether void of fixed air.—With reſpect to old flowers of zinc, I entertain no doubt, as they efferveſce with acids, and yield a fluid endowed with all the properties of fixed air; when newly made, they ſcarcely excite any ſenſible motion; and even the old ones, by roaſting, are deprived of that volatile menſtruum which they had attracted from the atmoſphere. The ſame holds of

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(*m*) "In order to complete the proof of this fine theory, it would perhaps be requiſite to ſhow that the quantity of mercury which may be combined with 100 parts of marine acid, takes up more than 64 parts of fixed air, when it is precipitated by cryſtallized vegetable alkali; for it is not eaſy to preſume that this really happens, when it is conſidered, that the author has juſt aſſerted, that this metal gains, by ſuch a precipitation, an addition of only one third of its weight. It may be moreover obſerved, that ſeveral phænomena indicate the preſence of a quantity of phlogiſton in the intimate conſtitution of foſſil alkali. I have ſhewn that it reduces gold, in the ſame circumſtances in which vegetable alkali affords only an earthy precipitate.—(El. de Chem. Dij. tom. ii. p. 310). Now the colour of the mercurial precipitate may be explained juſt as ſatisfactorily by this hypotheſis." Morveau.

old ceruſſe;—new ceruſſe I have not yet examined (*n*).

## § XXII. *Fixed Air is a true Acid.*

From the foregoing experiments, we may conclude concerning the agreement of fixed air with acids; for from them it appears that this vapour excites a diſtinct ſenſation of taſte upon the tongue (§ V.); that it reddens tincture of turnſole (§ VI.); that it attacks fixed alkalis violently, and renders them mild; that a ſmaller quantity of it than of the ſtronger acids ſaturates them, renders them cryſtallizible, and leſs ſoluble (§ VII. VIII.); that by its union it makes volatile alkali more fixed, leſs odorous and penetrating, and cryſtallizes it (§ IX.); that when it juſt ſaturates pure lime, it takes away its ſolubility and acrimony, and cryſtallizes it, but that when ſuperabundant, it renders it again ſoluble (§ XI.); that it produces the ſame effects with terra ponderoſa (§ X.); that with magneſia, it conſtitutes a neutral cryſtallizable earthy ſalt (§ XII.); that with iron, zinc, and mangaueſe, it forms ſalts, which, when diſſolved

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(*n*) "This obſervation is of great importance, as it announces a metallic earth, free from all combination, either with phlogiſton or the aerial acid; and as it furniſhes the firſt exception to this general rule, That the metals do not loſe their *metallizing* principle, but to unite with another menſtruum, and reciprocally." Morveau.

in water, redden the tincture of turnſole, like all other metallic ſalts (§ XIV.—XVI.); that it exerts elective attractions, both ſimple and double, after the manner of acids (§ XX. XXI.); that it precipitates ſubſtances diſſolved in pure alkalis (§ XIX.); that its laſt particles, notwithſtanding its extraordinary volatility, adhere very tenaciouſly to boiling water, and are not without great difficulty entirely ſeparated from it, but that by congelation they are eaſily detached, in the ſame manner as by that ſame degree of cold the weak acids are concentrated (§ IV.); and finally, that it greedily attracts phlogiſticated matters (§ XVIII.). Every one of theſe properties belong to acids in general, and moſt of them are conſidered as characteriſtic marks which are peculiar to acids, and diſtinguiſh them from all other ſubſtances: either then, fixed air, being endowed with all theſe qualities, is an acid, or we are reduced to confeſs that no certain criterion of acids is yet known.

The acidity of fixed air being, as I think, demonſtrated, many reaſons induce me to apply to it the name of aerial, or atmoſpheric acid, as being adapted to its nature. It ſo much reſembles common air in levity, tranſparency, elaſticity, and other properties, that it is only of late they have begun to be diſtinguiſhed.—Beſides, in that aerial ocean, which, under the name of atmoſphere, ſurrounds our globe, this vapour is continually preſent, either free or entangled in combination with other bodies. Its exiſtence in the former ſtate is manifeſtly ſeen in phænomena which daily occur; lime-water every where ſeparates a cream, when expoſed to the open air, which does not happen in bottles perfectly cloſed; and never can happen, unleſs fixed air be in contact with its ſurface (§ XI.). Quick lime, expoſed for a long time to the atmoſphere, by degrees recovers what it had loſt in the fire, ſo as entirely to re-aſſume the nature of crude lime, and be unfit for the maſon's uſe, unleſs it be again deprived of its acid. Terra ponderoſa and magneſia, reduced to a ſtate of purity, in like manner recover from the open air their weight, power of effervefcing, and other loſt qualities. Pure alkalis are made mild in the open air, loſe their deliquiating quality, and form cryſtals which effervefce with acids, circumſtances which can only be aſcribed to their attracting fixed air. Since then, theſe phænomena all take place at every time, and in every part of the world, a quantity of uncombined fixed air, by no means inconſiderable, muſt be perpetually preſent in the atmoſphere.

But it is not only in an elaſtic and diſengaged ſtate that fixed air ſurrounds us, but it alſo ſeems to conſtitute a primary principle of common air. This ingenious conjecture of the indefatigable Dr Prieſtly comes now to be examined.

The experiment indicating this compoſition of atmoſpheric air, is as follows:—Let tincture of turnſole include a bubble of common air in a glaſs tube, bended into the form of a ſyphon; let either leg, filled to a certain height with mercury, be immerſed in a veſſel filled with that fluid metal; then, by means of an electrical machine, let ſtrong ſparks be plentifully paſſed from the mercury in one leg, through the bubble in the other. This being continued for ſome minutes, the ſurface of the tincture will be found to riſe higher in both legs, and to change its blue colour to a red; the tincture, thus reddened, recovers its blue colour in the open air. If, inſtead of the tincture, lime-water be uſed, it is rendered turbid, and depoſits an effervеſcing lime. In this caſe then, the air ſeems to be decompoſed, and to be divided into two different elaſtic fluids, one of which tinges the tincture of turnſole with a fugitive red, is abſorbed by water, and precipitates lime-water, that is, is endowed with all the criteria of fixed air; but the other fluid does not combine with water, extinguiſhes flame, and deſtroys animal life, as it ſuffers no change from the vapour of phlogiſticated nitrous acid. That theſe phænomena do not depend upon the electric fluid alone, appears plainly; for if, by means of an air-pump, the bubble of air be ſo dilated that all the reddened tincture is expelled from the legs of the ſyphon, and in its place a blue tincture be poured in, to the ſame height, then, though the ſparks be paſſed through the bubble, as before, no veſtiges of fixed air appear. Hence then it appears, that ſomewhat which reddens tincture of turnſole, and precipitates lime-water, is found in the air, and has been taken away in the former operation.

We now know that common air conſiſts of three elaſtic fluids mixed together, viz. 1ſt, of the aerial acid, in its diſengaged ſtate, but in ſo ſmall a quantity, that it alone cannot impart a viſible redneſs to tincture of turnſole; 2d, of an air unfit for ſuſtaining flame, or being ſubſervient to reſpiration (this we may call vitiated air (*o*), until we are better acquainted with its nature and properties); and 3d, of air indiſpenſably neceſſary to flame, and animal life, which forms only about one fourth of common air, and which I call pure air. Here a queſtion may ariſe, which of theſe fluids has been altered by the electric aura? I am

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(*o*) The nature of this elaſtic fluid, which Dr Prieſtly has denominated *phlogiſticated*, ſeems to have been leſs elucidated than that of almoſt every other ſpecies. It is generated by phlogiſtic proceſſes, and immerſion of animal ſubſtances in nitrous acid: it is ſpecifically lighter than atmoſpheric air; is fatal to reſpiring animals, though ſome inſects live in it; it is reſtored by vegetation, and in ſome degree by agitation, in orange-coloured nitrous acid. B. This obſcurity has been cleared up by Mr Cavendiſh, whoſe late diſcoveries have rendered more ſervice to chemiſtry than thoſe of any perſon ſince Dr Black. If we admit the exiſtence of phlogiſton, it is nitrous acid and phlogiſton; if we reject it, it is nitrous acid deprived of all its vital air or acidifying principle; in other words, a conſtituent part of nitrous air and nitrous acid.

inclined to think the latter, inaſmuch as it attracts phlogiſton more violently than even the nitrous acid does: let us now ſuppoſe this air compounded of two principles, namely, of the aerial acid, and ſome other ſubſtance, which unites more readily with the electrical phlogiſton than with the aerial acid; when the electrical phlogiſton therefore is added, the aerial acid is ſeparated, and, as it were, precipitated. Although all this appears very probable, yet other experiments, in which, by means of phlogiſton, air is changed, without any appearance of the extrication of fixed air, prevent us from concluding with certainty concerning the compoſition of the air. Let us uſe, as an example, the ſulphurated ſalt of Stahl. I expoſed ſtrips of linen, wet with cauſtic vegetable alkali, for a ſufficient time to the fumes of burning ſulphur; I then put them into different cucurbits, and preſſed them to the bottom, ſhut the mouths very cloſely with wet bladders, and kept them in an heat of about 18° for 16 days;—at the end of that time I opened the mouth of one cucurbit under the ſurface of tincture of turnſole, which immediately ruſhing in, filled a little more than $\frac{1}{5}$ of the cavity: hence, herefore, it appears, that the phlogiſton had by legrees deſerted the vitriolic acid, and changed he included air, yet no redneſs could be perceied in the tincture. I opened the mouth of anher cucurbit, under lime water, which entered in the ſame manner, but ſhewed no ſigns of turbidneſs (*p*). If electrical ſparks extricate fixed air, purely by the addition of phlogiſton, why does not the ſame extrication take place in this laſt experiment?—It is indeed true, that in the former caſe the electrical phlogiſton penetrates the whole maſs much more violently, and thence may perhaps

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(*p*) Was the fixed air produced in this experiment abſorbed by the vitriolated tartar, as it was gradually formed, in conſequence of the diſſipation of the phlogiſton?—Perhaps this conjecture will not appear ſo very improbable, if we conſider that Dr Prieſtly obtained from ½ an ounce of that neutral ſalt, 1½ ounce meaſure of air, chiefly fixed; vol. ii. p. 116.—See alſo vol. v. p. 164, where he ſays, that he procured fixed air mixed with another ſpecies of elaſtic fluid, both from vitriolated tartar and Glauber's ſalt.

M. Morveau contends, that the experiment above related only proves that fixed air is produced by the electric ſpark taken in common air; and that, when a given quantity of air has been once expoſed to the influence of that fluid, no more fixed air is produced by freſh ſparks. He inclines to think that fixed air is generated by the combination of ſome other principle with pure air. Thoſe who adopt the opinion ſo ingeniouſly maintained by Mr Kirwan, in vol. lxxii. of the Phil. Tranſ. that fixed air conſiſts of dephlogiſticated air and phlogiſton, will readily ſuppoſe, that the fixed air is generated, not diſengaged, by the electrical fire. B.

We have been ſince taught by Mr Cavendiſh, that the aerial acid comes from the turnſole, which is burned by the electric ſpark; and that lime-water is not rendered turbid in this experiment.

perhaps decompoſe ſome primary principle; and perhaps if the circumſtances of our experiment were charged, the ſame effect will be produced; but the laws of ſound reaſoning oblige us to ſuſpend our judgement until a number of apt experiments ſhall determine the truth.

In the mean time fixed air may with great propriety be called the aerial, or (if more agreeable) the atmoſpheric acid; it might alſo be called the univerſal acid, as it is found in great abundance throughout all nature: but as it is uſual by that denomination to indicate that ſaline principle which, differently modified, produces all the other acids and alkalis; and as theſe properties cannot as yet be affirmed of fixed air, I think we ſhould abſtain from that name, as being ambiguous. I am not ignorant that the volatile alkali, and the marine acid, contain phlogiſton as one of their primary principles; and that, being ſpoiled of the inflammable principle, they are reſolved into elaſtic vapours: but the vapours which are in both caſes obtained, although not condenſable by cold, are not of the ſame nature, and neither of them is ſimilar to fixed air. The vitriolic acid, which is ſuppoſed to be contained in the atmoſphere, is neither every where, nor at all times, to be found there: I have for ſeveral years, by means of the pureſt fixed alkali, endeavoured to obtain it, but have not as yet obtained a ſingle particle. The vegetable alkali often contains vitriolated tartar, and the alkali of tartar itſelf is not always free from it, owing doubtleſs to the practice of fumigating wine-veſſels with ſulphur—unleſs, therefore, the purity of the alkaline ſalt which is expoſed to the air, be well known, errors can ſcarcely be avoided: the vitriolic acid, therefore, is not preſent in the atmoſphere, unleſs accidentally; the ſame may be ſaid of the nitrous and marine acids, which are ſometimes found in it.

## § XXIII. *Whether Acidity be eſſential to fixed Air.*

Although I imagine I have eſtabliſhed beyond doubt the acid nature of fixed air, yet ſome perſons may ſuſpect that this acidity is accidental, and to be aſcribed to a foreign acid, which is intimately united, by way of ſolution, with the common air;—but I hope the following obſervations will ſhew that this opinion is entirely without foundation.

(A) Let us ſuppoſe that common air, extricated from lime by vitriolic acid, is, notwithſtanding the waſhing, contaminated by that foreign acid, in ſuch a way that they can hardly be ſeparated; and that, while this union laſts, the air is rendered fixed;—now let lime-water be ſaturated with this elaſtic fluid, and the precipitated lime examined, it will be found in all reſpects ſimilar to cream of lime, or crude lime.—I would aſk, whether the common air, when it is again joined to the pure lime, retains the acid adulteration, ſion, united to it in the ſame manner as before? or, whether it ſhakes it off, and leaves it at liberty to unite with other matters? If the former be aſſerted, either the lime precipitated by fixed air ought to differ from common lime, which contains no vitriolic acid (a ſuppoſition contradicted by the moſt accurate chemical examinations), or the diſtinction between fixed air and common air is reduced to nothing; which overturns the hypotheſis of the generation of fixed air: if the latter, diſtilled vinegar would diſſolve the precipitated lime, leaving the gypſum untouched; but experiments made with the greateſt accuracy ſhew that diſtilled vinegar diſſolves the whole of the precipitate.

(b) Again, if the acidity depends upon a foreign admixture, different ſpecies of fixed air ſhould be produced by different acids. Now experience ſhews, that fixed air, extricated by marine acid, and properly waſhed, precipitates lime-water in the ſame manner with that obtained by vitriolic acid; and finally, that not the ſlighteſt difference in any of its properties can be diſcovered, whatever acid it is extricated by, provided it be ſufficiently depurated by waſhing. If the fixed air obtained by vitriolic acid poſſeſſes, on that account, the property of diſſolving iron and zinc, that procured by the nitrous ought to attack ſilver mercury; and that by aqua regia, gold and many other metals;—but experiments, which I made myſelf for that purpoſe, ſhewed me that no ſuch thing happens.

(c) Beſides,

(C) Beſides, grant that the fixed air expelled during efferveſcence is adulterated by an acid, whence does that which is produced entirely ſimilar by fermentation gain it; eſpecially that which appears in the beginning, a long time before even the firſt ſtage of fermentation has attained its height? If the acidity of fixed air be foreign, why can it not be ſo accumulated as to redden ſyrup of violets, paper tinged with turnſole, and the other vegetable blues?

(D) Finally, calcareous ſpar and magneſia afford genuine fixed air, purely by the force of fire (§ 11.); although, by the moſt ſcrupulous examination, they do not betray the ſmalleſt veſtige of a mineral acid. And this fixed air is produced, although they have been very minutely powdered and boiled for half an hour in a pure alkaline lixivium, and afterwards waſhed and dried, before they are put into the retort;—thus then all ſuſpicion of a foreign acid vaniſhes.

Since then, fixed air, rightly depurated, though extricated by the moſt different means, from the moſt different materials, whether by fire or by ſolution, is nevertheleſs always the ſame, and always acid; I conclude, with all the certainty attainable in phyſics, that acidity is a property eſſential to that elaſtic fluid.

Some conſider fixed air as the ſame with the vapour of phlogiſticated vitriolic acid; yet any one who but ſlightly compares the properties of the two, will eaſily ſee that this opinion is without foundation—for the one has an irritating pungent odour, and deſtroys the colours of any organiſed ſubſtance; and, to paſs over other circumſtances of moment, may eaſily be reduced to genuine vitriolic acid, neither of which is true of fixed air, which poſſeſſes a much leſs powerful attractive force than the other.

## § XXIV. *Specific Gravity of the Aerial Acid.*

By means of an hollow globe I meaſured the ſpecific gravity of fixed air in the ſame way as natural philoſophers weigh common air.—I compared the weights of equal bulks of fixed air and diſtilled water three ſeveral times. The firſt time I found the proportions as 1 to 555; the ſecond, as 1 to 563; and the laſt as 1 to 560. I employed, as nearly as I could, a moderate heat (15°) together with a mean height of the barometer (25,3) but yet could not avoid ſome minute differences.—The medium of the three obſervations is $559\frac{1}{3}$, or, in round numbers, 559,—ſo that its ſpecific gravity comes out 00,018;—now common air, in the ſame circumſtances, is ſcarcely 00,012,—ſo that fixed air is about 00,006 heavier than common air.

The noxious vapour which abounds in certain caverns is entirely of the ſame nature as the aerial acid; for it is abſorbed by water, and communicates to it a pungent acidity; it reddens tincture of turnſole, makes lime-water turbid, extinguiſhes flame, kills animals, and, above all, riſes but a little way, on account of its ſpecific gravity. In a pit which was opened in the year 1717, at the Pyrmont Spa, the loweſt ſtratum of air, which is ſcarcely two feet in depth, is noxious, and when the ſun's rays can reach down to it, it may be perceived, by means of the exhalations mixed with it. Over the medicinal fountain itſelf there is a poiſonous ſtratum of air hardly a foot in depth, ſo that geeſe, by means of their long necks, can ſwim acroſs it without damage. The exhalations from the caves in the neighbourhood of the Swalbach, and other acidulous waters, are of the ſame nature. In the Grotto del Cane, near Naples, men, and even large dogs, ſuffer nothing while they ſtand erect; but if the noſtrils of any animal are brought near the ground, it is inſtantly ſeized by ſtupefaction.—This deadly vapour may be ſeen like a very ſubtile ſmoke, which in ſummer riſes about a foot from the ground; but in winter not above a few inches.

From the gravity of fixed air it alſo follows, that the lower ſtrata of the atmoſphere abound more with it than the higher; for the prodigious quantity which is generated by fermentation, putrefaction, effervеſcence, and other natural operations, every day going on, for the moſt part remains cloſe to the ſurface of the earth;—this muſt be again fixed by the continual generation of new bodies. Certain portions of it alſo, which are perhaps generated from the common air, in the higher regions of the atmoſphere, by lightning, and by various meteors, muſt by degrees all ſubſide, were it not that the continual agitation of the atmoſphere, mixing the common air and aerial acid with each other, together with the friction and the ſmallneſs of the difference in ſpecific gravity, contribute much to prevent it: which, together with the above-mentioned diminution of it, all contribute to avert deſtruction from the animal world. Hence I imagine the reaſon is plain why higher ſituations are in general more healthful than lower ones (*r*); and I have no doubt but that various diſorders, both epidemic and endemic, ariſe

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(*r*) Though elevated ſituations may in general be more ſalubrious than low ones, it is not to be ſuppoſed that the healthfulneſs of any place is in proportion to its elevation, on account of the different quantities of aerial acid to be found in different ſtrata of the atmoſphere. But it is not unuſual with thoſe who are contemplating one of the principal agents in nature, to aſcribe too many effects to it. M. Sauſſure found that the air of the valley of Chamouni abſorbs a volume of nitrous air equivalent to 28 grains of water more than the air at the ſummit of the Buet. Three other experiments concurred with this to ſhew that the air of the ſummits of mountains is leſs pure than that of the vallies lying at the foot of them. The air on the glacier of Taléſre alone appeared, by the nitrous teſt, ſuperior to that of the valley of Chamouni. The air of Geneva was of ariſe from the different quantities of aerial acid in the atmoſphere. At the ſurface of the earth it is rarely found to form $\frac{1}{18}$ of the common air.

The aerial acid is not always of the ſame degree of tenuity, which ſeems to depend upon this, that water abſorbs certain particles more readily

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of equal goodneſs with that of Chamouni, and ſuperior to that of the plains of Piedmont.

"Since then," ſays M. Sauſſure, "of the tops of five mountains, four afforded an air leſs pure than the plains lying at their feet; and the only one on which the air is more ſalubrious than in the plains, owes that advantage to a particular ſituation; it ſeems as if we may conclude that the air, at a certain height, loſes ſomewhat of its purity.

"I ſhould, however, have been more cautious than to deduce a general concluſion from ſo inconſiderable a number of obſervations, if the fine experiments of S. Volta on inflammable air had not proved, that an immenſe quantity of this elaſtic fluid is conſtantly produced, which, as it is much lighter than common air, muſt riſe to the more elevated regions of the atmoſphere.

"It appears, therefore, that if the air of the low plains is rendered leſs ſalubrious by the groſs exhalations which its denſity enables it to ſupport; on the other hand, the air of mountains raiſed more than 500 or 600 fathoms [toiſes] above the level of the ſea, is vitiated by other exhalations, which do not leſs diminiſh its wholeſomeneſs, becauſe they happen to be lighter than common air; ſo that, even in the preſent inſtance, there is a certain medium, at which the denſity of the air, *ceteris paribus*, is beſt adapted to the life and health of man—I ſhould fix the height at that of the plains and great vallies of Switzerland, which are elevated between 200 and 300 fathoms above the level of the ſea." B.

than others. It is not wonderful that the union ſhould be continually retarded from beginning to end, as this effect is entirely conformable to the nature of attraction; yet the following phenomenon ſeems to confirm the former opinion:—

Let us ſuppoſe the bottle Q R filled with fixed air, and one half of it by degrees conſumed. A ſubſequent union will be effected, in a given time, more ſlowly with the remainder, than with fixed air which had not been expoſed to water, though the ſurface of contact be the ſame. Hence it would appear, that certain particles, either by reaſon of their figure, their magnitude, or ſome extraneous mixtures, are rendered more unfit for union with water (*s*).

## § XXV. *Aerial Acid extinguiſhes Fire.*

Fixed air not only prevents fire from being kindled, ſo as to prevent the exploſion of bombs and fire arms, but it alſo inſtantly and completely extinguiſhes a body red hot, and flaming; ſo that to determine the preſence of mephitic air by flame is a common experiment.

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(*s*) "Difference of figure between elementary particles ſeems repugnant to the theory of affinities, as produced by this figure; for it is evident that a body not having the ſame affinities, has not the ſame properties, conſequently cannot be the ſame body. I therefore think the laſt-mentioned cauſe the only one admiſſible. Morveau."

If a glaſs cylinder, A D, filled with aerial acid in the manner above deſcribed (§ 11.), and then ſtopped by a cover, be carefully inverted and opened, the fluid contained will, by its ſpecific gravity, remain there; let then a lighted candle or coal be immerſed in it, and in an inſtant all the fire will be extinguiſhed. But if the veſſel remain open, the upper ſtrata mix gradually with the common air, ſo that flame can at length ſubſiſt in them; and in this manner, by degrees, the whole maſs is changed; but the more ſlowly in proportion as the cylinder is more lofty, and the circumjacent air more tranquil. The ſame phænomenon may be obſerved on the ſurface of fermenting liquors.

The aerial acid very ſtrongly attracts ſmoak, extends it in a ſtratum parallel to its own ſurface, and holds it a long time. This may be obſerved in caverns where mephitic air is produced by means of the ſmoak of an extinguiſhed torch, or a gun fired over the noxious ſtratum (*f*).

## § XXVI. *Aerial Acid kills Animals.*]

In theſe experiments I generally employ the following apparatus:—A glaſs veſſel, A B (fig. 9.),

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(*f*) This amazing phænomenon is, I think, owing to the attraction of aerial acid for the water contained in the ſmoak.

when the animal is encloſed, is ſuddenly cemented to the wooden bottom, B C; this veſſel is perforated at the top by a hole, D; the tube, E F, which introduces the noxious vapour, is fitted cloſely to the bottom, that no air can eſcape; the noxious vapour expels the lighter common air through the hole D: at firſt, however, they are in ſome degree mixed together, which is the reaſon why the animal does not as quickly die as when at once immerſed in the aerial acid: but experiments have ſhewn me, that by this very circumſtance the phænomenon may be more eaſily diſtinguiſhed.

As ſoon as the noxious vapour ruſhes in through the tube E F, the animal looks about with great anxiety, in order to eſcape; it then begins to pant—the eye-balls are protruded—it trembles—and at length expires as if going to ſleep. By regulating the influx of aerial acid, the approach of death may at pleaſure be deferred. The difference in the ſpecies of animals, their age and vigour, make ſome difference: thus birds generally die ſooner than dogs; theſe ſooner than cats; amphibious animals endure longer; and inſects longeſt of all. With reſpect to age, the younger animals are leſs quickly deſtroyed, eſpecially thoſe that are ſomewhat accuſtomed to it; for ſuch as have been often expoſed to the open air in the very agony of death, and recover, are afterwards more ſlowly deſtroyed by that fluid than ſuch as are for the firſt time expoſed to it. After death, the lungs appear ſomewhat collapſed; they do not ſink in water, like thoſe of an animal which has periſhed in vacuo, but float; and often are in many places inflamed. The trunk of the pulmonary artery, the right ventricle of the heart, with its auricle, the vena cava, the jugular veins, and the veſſels of the brain, are diſtended with blood; and I have more than once ſeen a firm polypus in the right ventricle. The pulmonary veins, the aorta, the left ventricle of the heart, with its auricle, are generally flaccid. The irritability of the muſcular fibres all over the body is found deſtroyed: nor could I, either by blowing into it, by the knife, or by vitriolic acid highly concentrated, excite to motion the heart of an animal thus deſtroyed, although taken out warm (*t*).

Authors diſagree concerning the effective cauſe of death in this caſe; and it would be preſumption

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(*t*) I have ſeen the direct contrary in ſo many experiments, that I heſitate not to reject this account of the deſtruction of the irritability of the muſcular fibres. The author muſt have left his animals too long unopened; otherwiſe he would have ſeen the heart contract, when ſtimulated. The cauſe of death is the ſame, whether an animal be drowned in water, aerial acid, or any other kind of air, or whether it be killed by hanging. When the acceſs of air is prevented, the blood is not changed to arterial, and is therefore incapable of ſtimulating the left cavities of the heart.

tion in me to attempt the deciſion of ſo important a queſtion.—Contented if I have been able, in this Eſſay, to eſtabliſh the acidity of fixed air, which was my chief purpoſe, I have adapted all the experiments to the end propoſed with as much accuracy as I was able; I repeated them diligently, and conſidered them carefully;—I therefore thought it unneceſſary to particulariſe thoſe which have been made by other perſons, and for purpoſes different from mine, eſpecially as they cannot eſcape the obſervation of the learned reader (*u*).

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(*u*) Mr Bewly, in ſome letters, dated towards the cloſe of the year 1775, and publiſhed in the Appendix to Dr Prieſtly's 2d vol. deſcribes a ſeries of experiments, undertaken in order to prove the propoſition maintained in the foregoing Diſſertation. It will appear a little ſtrange, that he ſhould not have been appriſed of Profeſſor Bergman's opinion on the nature of fixed air, (for if he had known it, his candour would not have permitted him to paſs it over in ſilence), as it had been publiſhed by Dr Prieſtly, three years before the date of Mr Bewly's experiments. We are therefore to conſider the preſent inſtance as a confirmation of the obſervation, that the ſame diſcovery is often made by different perſons, without any communication with each other, when ſcience has arrived at a certain pitch of maturity. Of this truth Mr Scheele's diſcovery of dephlogiſticated air, without knowing that Dr Prieſtly had previouſly obtained the ſame elaſtic fluid, furniſhes another ſtill more remarkable example. On comparing the dates, it will be found, that priority of claim as evidently belongs to the

Swediſh profeſſor in the former, as it is acknowledged to belong to our induſtrious countryman in the latter caſe. On peruſing Mr Bewly's obſervations, it will be ſeen, that he was alſo led to adopt another opinion, advanced by Sir T. Bergman, and called in queſtion by M. de Morveau, viz. That fixed alkali is capable of uniting with a quantity of aerial acid exceeding that which is neceſſary for its ſaturation. B.

E.

## II.

## OF THE

# ANALYSIS

## OF

# WATERS.

### § 1. *A brief Hiſtory of the* ANALYSIS *of* WATERS.

MUCH time could not have elapſed, before mankind firſt began to perceive the difference of waters, although furniſhed with no other criterion than that of taſte. But the preparation of food, and the various arts and manufactures which afterwards began to be ſtudied, muſt gradually have ſuggeſted a difference in the properties and goodneſs of waters, with reſpect to certain purpoſes, although we are at preſent ignorant of the manner and order in which theſe diſcoveries occurred. Hippocrates judges thoſe waters to be moſt proper for common uſe, which are clear, light, void of taſte and ſmell, and which run from the eaſt; obſervations, the juſtice of which is to this day generally acknowledged, with the exception of the laſt, which perhaps, in the country of Hippocrates, reſted upon ſome local advantage. He (*a*) condemns, as worſt of all, ſuch as are hard, ſalt, aluminous, and the waters of lakes and marſhes. Pliny not only diſtinguiſhes waters into nitrous, aluminous, bituminous, ſalt, ſulphurated, acidulous, chalybeate, ſalubrious, poiſonous, medicated, cold, warm, hot, ſuch as boil pulſe ſlowly, ſuch as incruſt the veſſels in which they are boiled, ſuch as intoxicate, ſuch as change the colour of cattle, &c.; but mentions water boiled, and cooled again by ſnow, according to Nero's method; and aſſerts, that vitiated waters are reſtored by being boiled to one half (*b*).

But as to the art of accurately examining waters, with regard to their contents, we ſcarce find any traces of it worthy of obſervation, until the ſeventeenth century. Tabernæmontanus, whoſe true name was (*c*) Jacob Theodore, about the end of the ſixteenth century, enumerates a variety of the waters of Germany, and among the reſt Seltzer water; but he gives no analyſis of them. (*d*) Andrea Bacci, an Italian phyſician, whoſe

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(*a*) Lib. de Aëre, Aquis et Locis.

(*b*) Hiſt. Nat. lib. xxxi. paſſim.

(*c*) Waſſerſchatz. Frankf. 1593.

(*d*) Septem de Thermis Libri. Rom. 1596.

work was publiſhed in the year 1596, makes not the leaſt mention of analyſes of this kind, altho' no one before him had written ſo accurately upon the ſubject of waters.

The illuſtrious Mr Boyle, in the year 1663, had diſcovered the uſe of ſeveral precipitants. It had been before known, indeed, that ſyrup of violets was made red by vitriolic acid, and by lemon-juice: but this effect was attributed to ſome peculiar quality in theſe two liquors. Mr Boyle diſcovered this to be a property common to all acids; and was alſo the firſt who obſerved the green colour occaſioned by alkalis, which he inſtances in the juice of blue-bell. He mentions the blue ſolution of copper in volatile alkali; he relates that the colour of roſes is deſtroyed by the fumes of ſulphur, but heightened by its acid; that water tinged by Brazil wood grows yellow on the addition of an acid, while that tinged by cochineal has its red colour made more dilute; and that alkalis reſtore the original intenſity of colour; that ſilver is precipitated from nitrous acid by fixed alkali, by common ſalt, and by marine as well as vitriolic acid, but not by volatile alkali; that ſalited ſilver grows black in the open air; that vitriol of mercury grows yellow, when waſhed with water; that mercury diſſolved in acids yields a white precipitate, on the addition of volatile alkali, but with fixed alkali a ſediment of an orange colour, which colour, on the addition of vitriolic acid, immediately diſappears, as does afterwards the whole of the precipitate; and that ſilver is as it were gilded in ſolutions of a ſulphureous nature; together with ſeveral other circumſtances, many of which had doubtleſs been diſcovered (*e*) before. Thus, to paſs over other inſtances, Gaſſendi ſays, that tincture of roſes has its colour heightened by vitriolic acid.

Nearly about the ſame time Dominic du Clos, at the firſt inſtitution of the Royal Academy of Sciences at Paris, in the year 1667, attempted to examine all the waters of France, and continued his inveſtigation for ſome years. He made uſe of ſeveral precipitants beſides thoſe above mentioned, ſuch as infuſion or powder of galls, and juice of the flowers of leſſer iris, to which he afterwards added martial vitriol, and juice of turnſole. He examined the reſiduum after diſtillation, inveſtigated its figure by the microſcope, its flavour, its ſolubility in water, and put its properties to the teſt of hot iron.

So long ſince as the year 1680, ſome remarkable experiments upon this ſubject made by Urbanus Hierne, were publiſhed in Sweden. This very expert chymiſt makes three claſſes of acidulous waters; namely, the acid, the vinous, and ſuch as contain a latent acid; he affirms that each of them contains a peculiar ore, moſtly martial,

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(*e*) Experiments touching Colours. Oxon. 1663.

together with a ſmall portion of ſulphur, either manifeſt, as in the acid gas of Spa, Pyrmont, and other waters of that nature; or occult, being diſſolved by a concealed alkali; or as yet in a naſcent ſtate. He conſiders the examination of the reſiduum as of little conſequence, on account of the loſs of the volatile particles; and thinks weighing uſeleſs, imagining that volatile ſpirits do not gravitate. He thinks that the tinging linen will detect waters ſaturated with a mature ore, but will not diſcover acidulous waters: he denies that the goodneſs of medicated waters can be determined by infuſion of galls alone, inaſmuch as all waters containing a groſs vitriolic ſalt ſtrike a black with that infuſion, while various acidulous waters of a more ſubtile nature, are not affected by it; nor does he think the tinging of raw fleſh ſufficient, as all vitriolic waters induce on it the very ſame colour (*f*).

In the year 1678, Hierne examined the acidulous (*g*) Medway waters, which had been diſcovered the year before, and ſoon after this ſpecies of water came into general uſe in (*i*) Sweden.

Mr Boyle again, in the year 1685, propoſed a number of ſubſtances for the more accurate exa-

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(*f*) Lilla Vattu-Profvaren. h. e. brevis Aquarum explorator. Stockh. 1683.

(*g*) De acidul. Medviens. 1680.

(*i*) Hiilphers de Font. ſoteriis Sueciæ.

mination of waters. He extols very much the volatile hepar ſulphuris, diſtilled from fixed alkali, ſulphur, and ſal ammoniac; this inſtantly grows black, either with green or blue vitriol; hence he thinks that concealed ſulphur may be diſcovered by vitriol; he obſerved that ſolution of arſenic grows black, and is precipitated by vitriol; he alſo affirms that he was acquainted with a method of diſcovering common ſalt in water, without any evaporation, but he does not deſcribe the method (*k*). He can ſcarcely, in this caſe, allude to ſolution of ſilver, as, though known before, it was then but little uſed, but afterwards began to be more frequently employed; for in the year 1697 it was applied to this purpoſe by Nic. Valerius, a Swede, who in his travels examined the hot waters of Aix; and, beſides the above-named ſubſtances, employed ſolutions of nitre, common ſalt, ſal ammoniac, and ſaccharum ſaturni, the acids of nitre and ſea-ſalt, and ſpirit of ſal ammoniac (*l*).

About the beginning of the preſent century other ſubſtances began to be uſed: in the year 1699, D. Regis and Didier employed tincture of mallow-flowers, which is made red by acids, and

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(*k*) Apparatus brevis ad naturalem & experimentalem Aquarum Mineralium Hiſtoriam, concinnatus in forma Epiſtolæ, Lond. 1685.

(*l*) Tentam Phyſico Chim. circa Aquas Thermal. Lugd. Batav. 1699.

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green by alkalis (*l*). At the ſame time Boulduc introduced lime-water, and vinegar of lead. Some perſon ſent to Aix by Burlet mentions with aſtoniſhment a ſilver cup, which having been kept for three days in the Bath water, became as it were gilded, a phænomenon long before known to Boyle, and by him aſcribed to ſulphur: it was afterwards accounted for upon the ſame principle, by Homberg (*m*).

In the year 1707, Burlet availed himſelf of ſolution of alum, paper tinged blue by turnſole, the ſame paper afterwards reddened by vitriolic acid, diſtilled vinegar, tincture of damaſk roſes extracted without acid, together with ſome other ſubſtances. In the ſame year too, Geoffroi ſubſtituted broad open glaſs veſſels to the cloſe retorts, which had been uſed until that time.

Beſides, in 1726 and 1729, Boulduc employed various other contrivances. For inſtance, until that time evaporation had been continued to dryneſs, and the ſaline part of the contents again diſſolved; but Boulduc thought it more expeditious either to ſeparate the ſtrata of the whole reſiduum, or to ſeparate the different ſubſtances, in order as they preſented themſelves during the evaporation. He alſo ſhewed the method of diſcovering,

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(*l*) L'Hiſtorie de l'Acad. des Scien. de Paris, 1699.
(*m*) Ibid. 1707.

vering, by precipitation with highly-rectified ſpirit of wine, the ſalts contained in any water; without expoſing it to heat (n).

From hence it appears, that the principal precipitants at preſent known were in uſe at leaſt from the middle of the ſeventeenth century; but if we examine the concluſions deduced from the obſervation of their effects, we ſhall be forced to acknowledge that they have been frequently unſatisfactory, and often more or leſs falſe.

It would be tireſome and uſeleſs to relate the opinions of the ancients concerning the heterogeneous matters found in water. Theophraſtus Paracelſus was of opinion, that all the ſpecies of earths with which he was acquainted, together with ſalts, bitumens, and certain metals, might be ſuſpended and carried about by that fluid: but, laying aſide theſe unproductive ſpeculations, we ſhall proceed to a period more advantageous to natural philoſophy. It has been already obſerved, that alum was long ſuppoſed to be preſent in waters; nay, D. Giure, in the year 1669, contended that the peculiar nature of acidulous water was not conſtituted by vitriol but by alum, and a certain vein of ſoft iron, or, as he calls it, the ens primum of that metal. This, ſo far as regards the alum, was however ſoon contradicted by Du Clos.

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(n) Mem. de l'Acad. de Paris, 1726 and 1729.

—At preſent, alum is very rarely found in natural waters.

Du Clos at the ſame time ſpeaks of a certain ſalt, ſimilar to gypſum; but Mr Allen (*o*) was perhaps the firſt who obſerved in waters a ſalt conſiſting of vitriolic acid and lime, and which he calls ſelenite. By the word *nitre* nothing more was formerly underſtood, than natron, or mineral alkali, which Hierne firſt obſerved in the acidulous waters of Egra (*p*), and F. Hoffman afterwards diſcovered in ſeveral medicated ſprings (*q*). The nature of this ſubſtance was accurately explained by Boulduc, in the year 1729.

The ſal catharticus amarus, or more properly, vitriolated magneſia, has been in high eſteem at Epſom, from the year 1610; and in 1696 Dr Grew publiſhed a ſmall treatiſe upon that ſubject; but, although it was found in the waters of Seidlitz, Seidſchutz, and at ſeveral other places, and was conſumed in great quantity, yet the true compoſition of it remained unknown until the year 1755, when the celebrated Dr Black (*s*) undertook the accurate examination of the nature of magneſia, the preſence of which, even united with fixed air alone, was afterwards diſcovered in

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(*o*) Nat. Hiſt. of Min. Waters of Great Britain, Lond. 1711.

(*p*) Brevis Aquarum Explorator.

(*q*) Opera, tom. v.

(*s*) Edin. Acts, tom. ii.

ſeveral waters (*t*). Glauber's ſalt is found in many ſprings, and is often confounded with vitriolated magneſia. About the end of the ſeventeenth century a new method of detecting common ſalt was diſcovered, although its taſte, and the form of its cryſtals, had been before that time generally conſidered ſufficient for the purpoſe.

In the year 1682 Liſter diſcovered lime in waters; and in 1752 Le Roy found ſalited lime in the laſt lixivium (*v*).—Margraaf diſcovered ſalited magneſia in 1759 (*u*); and F. Home nitrated lime in 1756 (*x*). As vitriolated water ſtrikes a black colour with galls, and as moſt acidulous waters poſſeſs that property, it was immediately ſuppoſed that ſuch waters contain a vitriol; Theophraſtus Paracelſus (*y*) imagined he had put that matter beyond doubt; but others, who by evaporation in vain attempted to obtain cryſtals of vitriol, began to entertain doubt of the fact, yet by different ways endeavoured to get rid of the difficulty:—Some alledged that theſe waters contained neither iron nor vitriol, but a ſoft ore, as they called it, an ens primum of that metal—others had recourſe to a volatile vitriol, &c.

(*t*) Acta Stockh. 1773.

(*v*) Mem. de l'Acad. de Paris.

(*u*) Mem. de l'Acad. de Berlin.

(*x*) Experiments on Bleaching. Edin. 1756.

(*y*) De Thermis.

In the beginning of this century, F. Hoffman attempted to eſtabliſh a new theory of mineral waters, denying that there was in the acidulous waters any true and actual acid: he grants indeed, that an acid vapour does exiſt, which, together with a certain elaſtic etherial principle, which he calls ſpiritus mundi, conſtitutes the ſpirit and life of the medicated waters; but he conſiders this as volatile, and therefore eaſily diſſipated. On the contrary, he inſiſts that the acidulous waters are alkaline, becauſe they effervesce with acids, and change the colour of ſyrup of violets to a green: theſe are marks, however, which we know to be ambiguous (§ VII.). As we are not acquainted with any alkali but ſuch as has paſſed through fire, and as alkalis are conſequently conſidered as the products of fire, many perſons denied the poſſibility of their exiſtence in waters (*z*). Hoffman himſelf thinks that the alkali originates from a ſpirit of ſulphur, which, according to the degree of its ſubtlety, would form with lime an alkalis either fixed or volatile;—Henckel thinks the alkali derived from common ſalt, though he owns he is ignorant how its acid can be expelled.

At length Dr Seip (*a*) gave an explanation, which was thought to remove all the difficulties

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(*z*) Opera, tom. v.

(*a*) Beſchreibung der Pyrmontiſchers Mineral Waſſer, 1771.

completely: he, with many of the ancients, ſuppoſes that the genuine mineral ſpirit is the volatile vitriolic acid; but as the ancients (from the ſudden change which the water undergoes on expoſure to air) concluded that this volatile ſubſtance flew off, he, on the other hand, contends, that the ſubtile acid which had formerly been united with iron, now forſakes the metal to unite with the alkali, which in the ſubterraneous caverns could not exert its ſuperior attractive power; and hence it is that the remarkable change which acidulous waters undergo when expoſed to the air, takes place: this ſpirit, he thinks, may be again expelled by diſtillation, and then obtained in its proper form. How far this explanation is agreeable to truth, will be ſeen (§ VIII.)

In the year 1748, Dr Springsfield (*b*) delivered it as his opinion, that air was the effective cauſe by which the contents of the ſubtile waters were kept in a ſtate of perfect clear ſolution, becauſe the departure of air always occaſions a turbidneſs and precipitation. And this opinion was afterwards further confirmed; for, in the year 1755, Venel's Memoirs on Seltzer water were publiſhed; in which, by very convincing arguments, he ſhews that the volatile ſulphureous acid is not the true mineral ſpirit, which, on the contrary, he contends is no other than the air itſelf; and he demonſtrates

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(*b*) Iter Medicum ad Aquas Spadanas.

monſtrates theſe propoſitions by arguments both analytical and ſynthetical (*c*); and, although he did not arrive at the truth altogether, it muſt yet be confeſſed, that he came nearer to it than any one before his time: he alſo attempted to prepare Seltzer water artificially. It is to be lamented that this very acute chymiſt, who ſuperintended the examination of the waters in France, did not publiſh any thing more upon that ſubject before his death.

It is at length ſhewn, by incontrovertible experiments, that the genuine mineral ſpirit, which gives character and life to the cold mineral waters, is altogether the ſame with that fluid which is now called fixed air: this principle is common to the Seltzer, Spa, and Pyrmont waters; but different ſalts, in different proportions, determine the different ſpecies of theſe waters.

Hence water, by bare impregnation with fixed air, cannot properly be called either Seltzer, Spa, or Pyrmont; nor can he be ſaid to underſtand the artificial preparation of theſe waters, who merely knows the method of ſaturating water with fixed air.—The particular quantity of the different ſalts which conſtitute the peculiar nature of each, muſt alſo be known.—The vapour which is found in hot baths conſiſts ſometimes of the aerial acid, as in the Caroline waters of Bohemia, but is fre-

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(*c*) Mem. der Sc. Etr.

quently of a different nature, as we ſhall ſee hereafter.

In the year 1771, at Upſal, ſeveral perſons made uſe of waters artificially prepared, which exactly reſembled the natural waters of Seltzer, Spa, and Pyrmont, not only as to the volatile part, but as to the entire contents (*d*); and the uſe of theſe waters afterwards obtained through moſt of the provinces of Sweden.

In the year 1772, Dr Prieſtly publiſhed a book at London, in which he taught how water might be ſaturated with the fixed air expelled from chalk by vitriolic acid.—Mr Lane had before employed fermentation for the ſame purpoſe, with the addition of iron, by which the water became a chalybeate.

The hepatic vapour, with which many hot baths are impregnated, has occaſioned much perplexity, becauſe ſulphur cannot artificially be obtained from them, though it ſublimes ſpontaneouſly, as at Aix.—Of thoſe who have laboured in this field it is ſufficient to name Charles Lucas, who yet did not ſucceed (*e*). At preſent the myſtery is unfolded (§ IV. VII. F. VIII. E.)

Finally, I ſhould mention, that the knowledge of the heterogeneous matters contained in waters, lately acquired, has excited many to under-

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(*d*) Vet. Acad. Handl. 1773.

(*e*) Eſſay on Waters. Lond. 1756.

take a claſſification of waters, according to their contents. On this principle the celebrated Profeſſor Sir J. G. Wallerius, publiſhed, in the year 1748, his Syſtema Hydrologicum (*f*).—F. A. Cartheuſer, in 1758 (*g*), publiſhed a work of the ſame kind; as did alſo Mr Monnet, in 1772 (*h*); not to mention thoſe who, limiting their reſearches to the waters of certain countries, have not treated the ſubject at large.

The nature of the preſent Work does not permit me to ſpend any time in relating the ſeveral diſcoveries of the moderns, which have led the way to a complete examination of waters: beſides, theſe are all to be found in the modern books. Let the candid and ſkilful judge whether the demonſtration of the acid nature of fixed air, the ſolution of chalk and magneſia in water, by means of that ſubtile menſtruum, and the analyſis and ſyntheſis of Seidſchutz, Seltzer, Spa, and Pyrmont waters, have contributed any thing to that purpoſe.

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(*f*) Wattu-Riket. ad Fin. comparet brevis Introd. ad Aquas examinand.

(*g*) Rudimenta Hydrol. Syſt. Fr. ad. V. 1758.

(*h*) Nouv. Hydrologie, 1772.

## § 11. *The Examination of Waters highly neceſſary.*

Water, conſidered by itſelf, and free from any heterogeneous mixture, is, as far as conjecture can reach, always of the ſame nature; but, during its paſſing over or penetrating various ſtrata, it is loaded with heterogeneous matter, more or leſs, according to circumſtances; very ſubtile powders being partly mechanically ſuſpended in it, and partly united intimately with it, in the way of chymical ſolution: hence no water is ever found upon the ſurface of the earth in a ſtate of perfect purity; nay, even rain and ſnow-water, although elaborated by the peculiar powers of nature from the moſt ſubtile vapours, with a degree of perfection inimitable by art, theſe, I ſay, though collected with all poſſible care, are yet found variouſly contaminated, according to the ſeaſons of the year, the climate, and other circumſtances.

The heterogeneous particles which waters contain differ with reſpect both to quality and quantity: hence it is that ſome are fit for the uſes of life, others unfit, noxious, or even ſometimes mortal; while others are found extremely efficacious in curing, or at leaſt in alleviating diſtempers. The medicinal waters differ very much in power, according to the quantity and quality of the particles contained in them: hence ſome which experience ſhews to have been employed with the beſt ſucceſs in certain caſes, in others may prove either inert or noxious. In the brewing of malt liquors, the baking of bread, the boiling of pulſe, the waſhing and bleaching of linen, the dying of different ſubſtances, the preparing of hides, ſkins, and paper, and in a number of other arts, the quality of the water employed is of ſo much conſequence, that, unleſs one be choſen fit for the purpoſe, the whole proceſs fails.—Water is uſed in conſiderable quantity in the preparation of food, and always conſtitutes the greater part of our drink; inſomuch that if we allow one kanne per diem to each adult, our calculation will rather fall ſhort, than exceed.

Hence it readily appears how a quantity of pernicious heterogeneous matter, though ſmall, being daily accumulating, may ſoon lay the foundation of numberleſs diſeaſes.

From what has been ſaid, I believe it is ſufficiently obvious, that the analyſis of waters is highly neceſſary, not only as a ſpeculative branch of natural philoſophy, but as ſubſervient both to public and private advantage.—From thence we are enabled,

1ſt, To chuſe the pureſt water for internal uſe.

2d, To avoid ſuch as is either unfit or noxious.

3d, To form a proper judgement concerning ſuch as are uſeful in medicine. Thus, if long experience has ſhewn the efficacy of the water in a certain fountain, and if at the ſame time the contents of that water be known, we are enabled to anticipate the experience of years, and inſtantly to form a judgement concerning the virtue of other waters, which exactly reſemble in their contents the water whoſe properties are already eſtabliſhed.

4th, To ſelect ſuch waters as are beſt adapted to the ſeveral arts and manufactures.

5th, To amend the impure (in ſcarcity of good water), and to ſeparate from it thoſe heterogeneous particles which chiefly impede its uſe.

6th, To imitate ſuch as are celebrated for extraordinary virtues, if a ſufficient quantity of the natural water cannot conveniently be had.

### § 111. *An accurate Analyſis of Waters is juſtly conſidered as one of the moſt difficult Problems in Chymiſtry.*

In proportion as an ingredient forms a ſmaller part of a compound ſubſtance, the more difficult it is to diſcover that ingredient, becauſe it is the more inveloped and hidden.—By means of fire we ſometimes diſcover $\frac{1}{12000}$ part, and even ſometimes a ſmaller proportion;—but in the analyſis of waters it is often neceſſary to detect $\frac{1}{50000}$, nay $\frac{1}{100000}$.

When the ſubſtance contained is not only ſmall, but alſo compoſed of different ingredients, the ſeparation becomes ſtill more difficult. Sometimes the heterogeneous matters in water amount only to $\frac{1}{20000}$, yet this is found to be compoſed of ſix, ſeven, or eight different ingredients, mixed together in ſuch a manner as to be eaſily confounded; it is, notwithſtanding, neceſſary to determine the quantity and quality of each.

Add to this, that ſome of the contents are ſo ſubtile as to elude the ſenſes, or ſo volatile as to fly off imperceptibly; ſome of the principles alſo are decompoſed during the examination—hence they require to be inveſtigated by peculiar contrivances.

It may be thought that the difference of a few grains in a kanne will not eſſentially alter the peculiar virtue of the water; but experience ſhews the contrary very clearly.

Theſe circumſtances will ſerve to ſhew the difficulty of the queſtion before us, even to thoſe who are altogether ignorant of chymiſtry.—And perſons who are even more than moderately ſkilled in that ſcience, muſt exerciſe peculiar addreſs, in order to perform the neceſſary operations with ſufficient accuracy. We can by no means therefore imagine, that powder of galls and ſyrup of violets are altogether ſufficient for this purpoſe.

I ſhould now proceed to deſcribe the method which I found moſt convenient in conducting this proceſs; but it will be advantageous, previouſly to know what heterogeneous ſubſtances are uſually found in cold waters.

## § IV. *What heterogeneous Matters are generally found in Waters.*

Very minute particles of flint, lime, magneſia, and clay, are ſometimes found mechanically ſuſpended in water. The argillaceous particles obſcure its tranſparency, and render it of an opal colour; the others occaſion variations which are leſs obſervable, becauſe the ſubtilty of their particles and the ſurrounding water render them tranſparent.—All theſe ſubſtances, when ſufficiently comminuted, acquire a ſurface ſo large, in proportion to their weight, that the friction neceſſary to be overcome in their deſcent becomes ſuperior, or at leaſt equal, to the difference of ſpecific gravity between the particles of the earth and thoſe of the water, which is the force with which the earthy particles tend to the bottom; and ſo long as this equilibrium takes place, the particles, once diffuſed in the water, will remain ſuſpended.

But various ſubſtances are found united with water, and with each other, much more intimately, that is, by means of chymical ſolution—theſe are now to be enumerated, and to each we ſhall ſubjoin a reference indicating the place, in the following pages, where the ſpecific nature and quantity of each of them are particularly treated of.

*Pure air* is contained in moſt waters, in the proportion of about one cubic inch to a kanne; this, when expelled by boiling, or by the air-pump, is gradually recovered from the atmoſphere (VII. S; VIII. A, B.)

*Aerial acid* alſo is found in every water, but in very unequal quantity, from $\frac{1}{100}$ of the bulk of the water, to a bulk equal to that of the water itſelf. This, as well as the pure air, by its dilatation under the receiver, produces a number of bubbles;—it communicates to water an agreeable, pungent, and refrigerant flavour (VI. A, B, C; VII. A, F, K, S; VIII. A, B, C, D.)

*Inflammable air* ſometimes iſſues from waters; this ſpecies of air, however, is not united with the water, but riſes from the bottom, and is expanded at the ſurface.

*The other acids*, in a diſengaged ſtate, are only found in waters accidentally (VI. C; VII. A, H; VIII. D.)

*Vegetable alkali* is rarely found in waters, and almoſt always in combination (VI. C; VII. B, C.); ſometimes vitriolated or ſalited, but more frequently nitrated (XI. B, 1, 2, 3.)

*Mineral alkali*, however, often occurs, either aerated, vitriolated, or ſalited (VII. F; XI. B, 1, 2, 3.)

*Volatile alkali* is ſometimes preſent, probably communicated by putrid vegetable or animal ſubſtances (VI. B, C; VII. B, C; VIII. F.)

*Terra ponderoſa* is ſometimes accidentally found united with marine acid (VII. F, L; X. D, 6; XI. B, 4.)

*Lime* frequently occurs aerated, vitriolated, nitrated, or ſalited (VII. G; X. D; XI. A, C.)

*Magneſia* is not ſo frequently found; yet ſometimes it occurs either aerated, vitriolated, nitrated, or ſalited (X. D; XI. A, B, 4.)

*Vitriolated clay* (*i*), or alum, is rarely found in waters (VI. C; VII. N; X. D; XI. B, 4.)

Among the metals *iron* is moſt frequently diſcovered in waters, and that, aerated, (VI. F; VII. D, E; X. D, 4.) vitriolated, or ſometimes perhaps ſalited (XI. B, 5.)

*Mangane/e* has not yet been found, except ſalited, although it may poſſibly be diſcovered aerated or vitriolated (VI. F; X. D, 4; XI. B, 5.)

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(*i*) An ingenious Engliſh phyſician has detected an earthy ſalt, which one ſhould ſtill leſs expect to find i water. He has met with muriated or ſalited clay in N vil Holt water, which has long baffled the attempts chymiſts to analyſe it.—His analyſis has not been publi ed. B.

*Copper* has only been found vitriolated (VI. A, F; XI. B, 5.)

*Arſenic* very rarely, and in the form of a calx (XI. B, 5.)

*Extracts from vegetable and animal ſubſtances*, with which water, paſſing through ſtrata containing ſuch bodies, is ſometimes contaminated.

Somewhat of *an hepatic* nature is alſo found, eſpecially in hot waters, and ſometimes alſo in cold chalybeate waters; but in general it is ſo ſubtile that it inſtantly flies off in the open air, and manifeſts itſelf no other way than by its ſmell (VI. B.). A genuine hepar is rarely preſent, although it is fallaciouſly indicated by an hepatic vapour, conſiſting of ſulphur reſolved into the form of vapour by means of phlogiſton and the matter of heat; as is clearly demonſtrated in the Treatiſe on the products of ſubterraneous fire. The method of ſeparating the ſulphur in its proper form will be explained, (VII. F, T.)

I could not diſcover any certain ſigns of *bituminous oil*, it being immiſcible with water, unleſs by means of an alkali. Petroleum, agitated with diſtilled water, ſeparates again upon ſtanding. It muſt be acknowledged, however, that the water, even after the moſt careful filtration, ſtill retains a ſtrong bituminous ſmell; yet nitrated mercury occaſions no precipitate (VII. P.)

Theſe heterogeneous matters are never found all together, but are more or leſs numerous in different waters. Thus ſome of them are contained in atmoſpheric waters; others in thoſe found on the ſurface of the earth; and, finally, others in ſea-water.

*Snow-water* contains a ſmall quantity of ſalited lime, together with ſome ſlight veſtiges of nitrous acid; this water, when newly melted, is totally void both of air and of the aerial acid; ſubſtances which are found, in greater or leſs quantity, in almoſt all other waters:—and hence it is, perhaps, that ſnow-water is noxious to animals.

*Rain-water* is generally contaminated with the ſame ſubſtances as the former; but in greater quantity: it is obvious that theſe waters, while ſuſpended in the air, muſt collect and abſorb the various heterogeneous matters with which the atmoſphere abounds, and therefore can never be obtained pure. Immediately after long-continued rain or ſnow, theſe waters are found leaſt loaded with heterogeneous matter.

*Spring-water*, when of the pureſt kind, contains but little heterogeneous matter, otherwiſe we find in it aerated lime, ſalited lime, common ſalt, and ſometimes a ſmall quantity of alkali.—Thoſe ſprings which are called mineral alſo contain gypſum, aerated and vitriolated magneſia, vitriol, aerated iron, &c.

*River-waters* are often ſo much purified by their motion as to contain nothing more than aerated lime, common ſalt, and ſometimes a little alkali. Theſe are generally lighter than ſpring-waters, and the more pure, in proportion to the rapidity of their courſe, and the hardneſs of the bottom over which they run.

*Well-waters*, beſides a large quantity of the above-mentioned ſubſtances, often afford gypſum and nitre.

*Lake-waters* are leſs clear than any of the former, they are alſo heavier, and depoſit ſpontaneouſly ſome earthy ſediment: they ſometimes contain all the ſubſtances above recited; and beſides, are generally vitiated by an animal or vegetable extract.

*Marſh-waters* have leſs motion, and therefore are leſs clear, more heavy, and more vitiated by extractive matter; hence they generally exhibit ſomewhat of a yellowiſh brown colour.

*Sea-water* contains common ſalt, vitriolated and ſalited magneſia, gypſum, and a conſiderable quantity of the putrid extract, which is generated partly from the innumerable crowd of animals which there live, die, and are decompoſed; and partly is there collected by falling into it from the earth.

In examining the products of ſubterraneous fire, I have particularly enquired whence theſe heterogeneous matters, and the different degrees of heat in waters, are derived.

## § v. *Water may be examined in two different ways, by Precipitants, or by Evaporation.*

We attain the knowledge of the heterogeneous matters in water chiefly by two methods, by precipitants, and by evaporation. Precipitants are ſubſtances which, on being added to waters, either immediately, or after ſome ſhort time, by altering their colour, or diſturbing their tranſparency, ſhew the heterogeneous matters they contain. Theſe, for the purpoſe of expedition, are very commodious; but they do not afford an accurate deciſion, eſpecially when the queſtion is concerning quantity. The weight of the precipitate may often, indeed, be of conſiderable uſe even in that view, as ſhall preſently be ſhewn, though it has not yet been employed for that purpoſe.

The other method conſiſts in ſeparating the contents by evaporation and cryſtallization.

When there is time ſufficient, and we wiſh to examine a water very accurately, both theſe methods ſhould be employed, as they reflect mutual light upon each other, and the precipitants indicate the proper method of conducting the evaporation.

Finally, in order to form a right judgement, we muſt confirm our analyſis by ſyntheſis. For this purpoſe the pureſt ſnow-water, gently diſtilled, and freed from empyreuma by ſtanding in the open air, ſhould be employed; and when the heterogeneous matters which have been diſcovered are added in due proportion, the artificial water ſhould be preciſely like the natural in every circumſtance.

## § VI. *The Phyſical Qualities to be obſerved.*

In forming a judgement of the nature of waters, their ſenſible qualities afford no inconſiderable aſſiſtance.

(A) The ſight is capable of aſcertaining many circumſtances of conſequence.

A *clearneſs* equal to that of cryſtal indicates great purity. On the contrary, muddineſs, and a brown colour ſhew plainly that heterogeneous matters are ſo groſsly mixed with the water as to obſtruct the paſſage of the rays of light. When the bottom is clay or mud, the water is never perfectly clear; but when it runs over ſand it is in general extremely tranſparent.

Good water is entirely without colour, but it does not thence follow that all colourleſs water is to be conſidered as good. A brown colour, verging to red or yellow, is found in dull ſtagnant waters; it is ſometimes occaſioned by iron, ſometimes by putrid extractive matter, and ſometimes, perhaps, is derived from ſome unctuous ſubſtance.

—A blue colour indicates vitriol of copper; a green, martial vitriol, &c.

If the water, upon agitation, emits a number of airy bubbles, a quantity of aerial acid is indicated.

(B) Good water has no *ſmell.*—Such as abounds with the aerial acid diffuſes a ſubtile and penetrating odour; ſuch as contains any portion of hepar ſulphuris yields a ſmell reſembling that of putrid eggs or fired gunpowder.—Stagnant and corrupted waters have a putrid offenſive ſmell.

(C) Water is the better, in proportion as it is the more completely void of taſte; yet a palate which is delicate, and accuſtomed to the taſte of waters, will diſcover ſome difference even among the pureſt.—Aerial acid occaſions a gently pungent aceſcent taſte;—a bitterneſs accompanies Glauber's ſalt, nitre, vitriolated, nitrated, or ſalited magneſia; as alſo nitrated or ſalited lime;—a ſlight auſterity proceeds from lime or gypſum—a ſweet aſtringency from alum—a ſaltiſhneſs from common ſalt—a lixivious flavour from alkali—an æruginous one from copper—and an inky one from iron.

(D) The ſpecific gravity lays in ſome degree a foundation for eſtimating the quantity of heterogeneous matters contained in water; but cannot always determine the matter with accuracy; becauſe, in ſome inſtances at leaſt, a mutual penetration may take place.

It is, however, in general true, that the lighter waters are more pure than the heavier; and for determining this point an hydroſtatic balance, and a good aerometer, are peculiarly convenient: but if theſe inſtruments are not to be had, an ordinary balance may be ſo managed as to compare the weight of diſtilled, or very pure ſnow-water, with that of other waters; this is done by means of a glaſs veſſel with a narrow neck, which is to be filled with water to a certain mark, and exactly weighed. The larger this veſſel is the better—but one containing a quadrans (*k*) or two, is generally ſufficient; for greater quantities require large weights, which are leſs accurate.

Finally, in whatever way theſe experiments are made, the waters compared muſt be of the ſame temperature, otherwiſe the concluſion will neceſſarily be fallacious.

(E) In the examination of waters, the temperature ſhould be determined by an accurate thermometer, and the following particulars obſerved: —whether the temperature of the water under examination is the ſame throughout the year, or whether it follows the changes of the atmoſphere—whether it freezes in winter—whether the hot waters form any depoſition during refrigeration—and whether, in conſequence of cool-

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(*k*) The Kanne contains 8 quadrantes, of which each contains 12½ Swediſh inches.

ing, their ſmell and taſte grow faint, or entirely diſappear.

(F) Local circumſtances are by no means to be neglected; to theſe belong the ſituation of the water, with reſpect to its geography both political and natural, and the elevation and properties of the ſurrounding ſoil. The quantity of the water ſhould alſo be obſerved—whether it remains the ſame at all ſeaſons of the year, or is obviouſly dependent upon dry weather and rain—whether it is ſtagnant—whether it runs ſwiftly or ſlowly—what quantity flows from the ſpring in a given ſpace of time—how many veins the ſpring conſiſts of, &c.

Whether the water depoſits in its bed a ſaline, an earthy, an æruginous, or an ochry ſediment—whether bodies lying in it are covered with a cruſt—whether ſaline efflorefcences are to be found in its neighbourhood—whether, in the channels and caverns through which it paſſes, ſulphur is ſublimed—whether it iſſues gently, or burſts forth with a ſort of ebullition, &c.

It is alſo proper to obſerve whether any vegetables grow in the water, and what—and whether any animalculæ live in it.

## § VII. *The Principal Precipitants.*

(A) *Tincture of Turnſole* is obtained from the pigment called lakmus, encloſed in a clean linen cloth, and ſteeped in diſtilled water. This water ſoon aſſumes a blue colour; but, when viewed againſt the light, it ſhews a violet tinge. If water be gradually added, the reddiſh tinge is diminiſhed, and at laſt entirely diſappears. This tincture is capable of detecting the moſt minute particle of diſengaged acid, by inſtantly growing red. A ſingle grain of highly concentrated vitriolic acid communicates a viſible red tinge to 172,300 grains (*l*), or 408 cubic inches, of the blue tincture.

In theſe experiments the ſame glaſs veſſel, or at leaſt veſſels nearly ſimilar, ſhould always be employed; for a ſmall difference in the diameter of the containing veſſel will occaſion a difference in the colour of the tincture, when viewed with the rays of light paſſing through it:—The veſſel which I make uſe of in theſe experiments is cylindrical, and 17 decimal (*m*) lines in diameter.

*Paper tinged by ſaturated tincture of turnſole*, with a little ſtarch boiled in it, is in certain caſes more readily changed;—a paper thus prepared, dipped into diſtilled water containing 12 grains of highly concentrated vitriolic acid to the kanne, and inſtantly taken out, is found to be

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(*l*) The Swediſh apothecaries pound conſiſts of 12 ounces, and each ounce of 480 grains.

(*m*) The Swediſh foot conſiſts of 10 inches, and each inch of 10 lines.

red—and this ſame paper, after being made red by diſtilled vinegar, ſerves to diſcover alkalis, by recovering its blue colour more or leſs completely. The preſence of an alkali may, to a certain degree, be diſcovered by means of the blue paper—its blue colour being heightened by the alkali. Diſtilled water, containing 40 grains of cryſtallized ſal ſodæ to the kanne, reſtores the blue colour to the paper reddened by vinegar, and a much leſs quantity of alkali renders the red colour obſcure.

We muſt not, however, be without the tincture itſelf, as being more ſenſible than the paper. Thus, water ſaturated with aerial acid, does not change the colour of the paper; yet one part of ſuch water makes about 50 parts of the tincture diſtinctly red. Nearly the ſame effect is produced by a ſingle grain of highly concentrated vitriolic acid, mixed with 3,445 grains of diſtilled water; therefore, ſuppoſing the ſpecific gravities of diſtilled water, concentrated vitriolic acid, and aerial acid, to be, reſpectively, as 1, 2, and 0,0018, we can in ſome meaſure compare the forces of theſe acids; for, upon calculation, they are found to be in equal weights, as 3,445 to 555, or as $6\frac{1}{5}$ to 1—and in equal bulk as 6,890 to 1.

(B) *The watery tincture of Braſil wood* is red, but readily takes a blue colour from alkalis; paper ſteeped in this tincture, with a little ſtarch boiled in it, is alſo red, and is equally fit for the preſent purpoſe; we may therefore diſpenſe with the tincture, the application of which is more troubleſome. One grain of newly cryſtallized ſal ſodæ, diſſolved in 4,295 grains of water, or (which is the ſame) 10 grains in a kanne, changes the red colour of this paper to a blue, faint indeed, but eaſily diſtinguiſhable; nay, an experienced eye will perceive the change, even though there be no more than ſix grains to a kanne.

Acids induce a yellow colour upon paper tinged by Brazil wood, and reſtore immediately the original red colour to the paper which has been made blue by alkalis.

(c) *Watery tincture of turmeric* is more or leſs changed to a brown by alkalis: paper tinged, as in the former caſe, by this tincture and ſtarch, poſſeſſes the ſame property with the foregoing; ſo that the tincture may be diſpenſed with. A ſingle grain of newly cryſtallized ſal ſodæ, diſſolved in 859 grains of diſtilled water, communicates to it the property of manifeſtly obſcuring the yellow colour of the paper: hence a kanne of water will not produce the ſame effect, unleſs it contains 49 grains of that alkali—acids render the yellow colour ſomewhat paler—volatile alkali produces changes upon all theſe papers, but theſe changes are very fugitive.

All theſe precipitants may be advantageouſly employed; the firſt, chiefly for diſcovering acids, and the two laſt for alkalis; it is true, indeed, that the blue of the turnſole, when changed to a red by acids, may ſerve to diſcover alkalis, ſo that the papers tinged by turmeric and Brazil wood may ſeem unneceſſary;—but we muſt obſerve that the latter of theſe two exceeds all other teſts in ſenſibility, ſo as even to diſcover certain earths diſſolved in water by means of aerial acid, ſuch as terra ponderoſa, lime, and magneſia. As to the former, it is indeed more ſlow; but by this very ſlowneſs it indicates in ſome degree the relative quantity; and beſides, when it is neceſſary to obſerve the change of colour occaſioned by alkalis by candle-light, the effect upon turmeric is more diſtinguiſhable.

Syrup of violets, therefore, is by no means neceſſary, eſpecially as, 1ſt, we can ſeldom have any genuine, at leaſt in Sweden; 2d, this ſyrup ſpontaneouſly acquires a red colour by fermentation; and, 3d, it is rendered green not only by alkalis, but by iron; which renders any concluſion drawn from thence ambiguous (*n*).

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(*n*) It may be doubted whether the reaſons here alledged are ſufficient to juſtify the learned Profeſſor in expelling ſo contemptuouſly ſyrup of violets from the place that it has ſo long held in the claſs of reagents. For, 1ſt, we are taught by chemical writers how to diſtinguiſh the genuine from the ſpurious ſyrup, viz. by ſolution of corroſive ſublimate, which changes the former to a green, while it reddens the latter. 2. It is not eaſy to be miſled by the alteration produced by the ſpontaneous fermentation, becauſe

The general rule, namely, That blue vegetable juices are made red by acids, and green by alkalis, is liable to two exceptions already known, viz. lakmus is rendered more intenſely blue by alkalis, and indigo diſſolves in vitriolic acid, without any change of colour. The blue juices of different vegetables are unequally affected by acids and alkalis; a circumſtance which demands a ſeries of experiments, in order to aſcertain the relative power of theſe ſalts. Pure aerial acid does not exert its power, except upon tincture of turnſole;—diſtilled vinegar changes ſyrup of violets, but has no effect upon the blue paper uſed for covering ſugarloaves, which yet is made red by the ſtronger acids; and ſo of the reſt.—Beſides, determined

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cauſe the experimenter cannot fail to perceive that beforehand. 3. He who has once compared the green produced by iron with that produced by alkalis, will eaſily be enabled to diſtinguiſh them on every future occaſion; the latter being a lively and pleaſant tinge, the former a yellowiſh dirty hue. 4. "When certainty," ſays M. de Morveau, "can only be attained by the coincidence of many reſults, this additional inſtrument, which in ſome caſes ſhews properties different from other analogous reagents, ought not to be entirely thrown aſide."

"M. Neuman and the Count de Saluces," adds the ſame judicious annotator, "have obſerved that ſyrup of violets paſſes from green to yellow when the alteration has been made by alkaline liquors, but continues green when the change has been produced by neutral ſalts." Mem. de Turin. B.

weights of vitriolic acid and of alkali ſhould be ſucceſſively mixed with different quantities of water, and their various effects upon the vegetable juices accurately noted. Thus, from a compariſon of their effects, the quantities of acids and alkalis, which are at preſent unknown, might in ſome degree be determined. But this uſeful inveſtigation requires a long train of experiments.

(D) *A ſaturated tincture*, extracted by ſpirit of wine from powdered galls: the watery tincture may alſo be employed but it ſoon grows mouldy.—By this tincture iron is diſcovered, being ſlowly precipitated:—if the quantity of metal be ſmall, the precipitate is purple; if large, black. Diſtilled water, containing three grains of cryſtallized martial vitriol in the kanne, upon the addition of a ſingle drop of this tincture, grows diſtinctly purple in leſs than five minutes. Yet three grains of martial vitriol contain no more than $\frac{1}{27}$ grain of iron.

(E) *The phlogiſticated alkali*, as it is commonly called, is beſt prepared from four parts of Pruſſian blue, boiled with one part of alkali in a ſufficient quantity of water. The clear liquor, ſaturated with an acid, muſt then be freed by filtration from the ſmall portion of Pruſſian blue which is ſeparated.—This preparation is extremely well adapted for diſcovering the ſmalleſt portion of iron. Diſtilled water, containing in the kanne one, or at moſt two grains of green vitriol, on

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the addition of a ſingle drop of this lixivium inſtantly ſhews a Pruſſian blue.—It alſo precipitates other metals;—copper it precipitates of a reddiſh brown colour—manganeſe, white; and ſo of the reſt.

(F) *Concentrated vitriolic acid* dropped in water immediately precipitates a ſpathum ponderoſum, if (which rarely happens) there be preſent any terra ponderoſa (IV.) The appearance of a number of bubbles ſhews whether there be any conſiderable portion of alkaline ſalt, lime, or magneſia, diſſolved by the aerial acid.—In order to occaſion a ſenſible effervеſcence there ſhould be at leaſt 390 grains of newly cryſtallized ſal ſodæ in a kanne, a quantity which however is not affected by ſtrong marine acid. The other mineral acids may be employed for the ſame purpoſe; but the effects of theſe will be always leſs remarkable, as they are leſs ſuſceptible of concentration to ſo great a degree as the vitriolic acid.—The concentrated nitrous acid is however very uſeful for diſcovering ſulphur in the hot waters which have an hepatic ſmell—for this acid, ſeizing the phlogiſton, precipitates the ſulphur which, by its means, was united to the matter of heat, though the ſulphur ſo combined is able to elude all the ordinary modes of examination;—concentrated nitrous acid, added in proper quantity, ſoon takes away the hepatic ſmell, thereby indicating a decompoſi-

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tion, and the ſulphur, ſubtilely divided, falls ſlowly to the bottom.

(G) *The acid of ſugar* is one of the moſt delicate teſts hitherto known for the diſcovery of lime, however mixed. A ſingle grain of pure lime diſſolved in a kanne of diſtilled water, ſhews white clouds and ſtriæ, if a ſmall portion of cryſtallized acid of ſugar be laid on the ſurface, or diſſolved and dropped in.

If the lime be in a ſtill ſmaller quantity, and the moſt minute cryſtal of ſaccharine acid let fall to the bottom, in a ſhort time a ſort of powder, conſiſting of ſaccharated lime, is found about the ſpot where the cryſtal falls. Scarce any water is entirely free from lime; and the pureſt, within twenty-four hours at leaſt, depoſits a portion of ſaccharated lime, although ſometimes ſo ſparingly as to eſcape obſervation, unleſs lines be drawn on the bottom of the veſſel with a glaſs rod.—Such is the water of Varby, which is juſtly enumerated among the beſt waters in Sweden.

*Eſſential ſalt of wood-ſorrel*, and the *microcoſmic ſalt*, alſo precipitate lime; but more ſlowly and leſs effectually than the acid of ſugar does.

(H) *Aerated fixed alkali* precipitates all earths and metals from their ſolutions: if the ſubſtance to be precipitated is eaſily ſoluble in the aerial acid, the cauſtic alkali in general effects a more remarkable ſeparation—generally, I ſay, for this is not always the caſe; for terra ponderoſa is not precipitated by that alkali.—If there happens to be preſent a diſengaged mineral acid, every particle of the aerated alkali emits bubbles.

(I) *Aerated volatile alkali* precipitates all earths and metals; but cauſtic volatile alkali has no effect on lime or terra ponderoſa. Diſtilled water, containing 98 grains of vitriol of copper to the kanne, is ſcarcely blue. If in the ſame quantity of water there be only 6½ grains, the copper is diſtinctly precipitated on poliſhed iron; but a few drops of ſolution of volatile alkali only occaſions a cloud, which is ſcarcely viſible. This cloud, if the vitriol be in larger quantity, ſoon changes from an aſh colour to a blue; and, when well diffuſed by agitation, communicates to the water a faint and duſky tinge. If the volatile alkali be ſuperabundant, all the precipitated copper is re-diſſolved with a moſt beautiful azure colour; for the quantity of this metal which is contained in four grains of blue vitriol, is ſufficient to give a viſible tinge to a whole kanne of water, if the copper be precipitated by a proper quantity of volatile alkali, and afterwards re-diſſolved by a ſuperabundance of the ſame alkali.

(K) *Lime-water* dropped into water which contains any aerial acid, renders it inſtantly turbid; becauſe that portion of the lime which is ſaturated by that ſubtile acid loſes its ſolubility.

(L) *Salited terra ponderoſa* is of conſiderable uſe in diſcovering the ſmalleſt veſtige of vitriolic acid, with whatever menſtruum it may be united; for this acid ſeparates terra ponderoſa from all others, forming with it a ſpathum ponderoſum, ſcarcely any of which water is able to take up. Diſtilled water, containing 12 grains of newly cryſtallized Glauber's ſalt to the kanne, on the addition of a few drops of ſolution of ſalited terra ponderoſa, immediately exhibits white ſtriæ.—If there be preſent no more than three grains of the Glauber's ſalt, after a few minutes a cloud forms at the bottom, which alſo happens even when there is but one grain in the kanne; but in this caſe the water muſt ſtand ſome hours before the cloud becomes viſible. Now, that we may the better judge how great the nicety of this precipitant is, let us conſider that 12 grains, 3 grains, and 1 grain of Glauber's ſalt, contain reſpectively no more than 3, 0,78, and 0,26 grains of vitriolic acid; ſo that this ſubſtance exceeds turnſole itſelf in ſenſibility.

(M) *Salited lime* is generally conſidered as a uſeful medium for diſcovering fixed alkali, for the aerated lime ſeparates, and falls to the bottom; but this experiment is ambiguous, becauſe, if any vitriolated magneſia be preſent, a double decompoſition takes place, and a gypſum is formed.

(N) *Solution of alum* has ſometimes been employed, but is of little uſe, as it is decompoſed by alkalis, either fixed or volatile, and by aerated, ſalited, or nitrated lime. If a piece of alum, the bulk of a ſmall pea, be put into the water under examination, in a quarter of an hour a ſpungy ſtratum is obſerved, horizontally ſuſpended near the bottom: however, as before obſerved, the cauſe of this phænomenon is uncertain, unleſs determined by other experiments.

Seven grains of alum diſſolved in a kanne of water, upon the addition of a ſingle drop of ſolution of alkali, either mild or cauſtic, inſtantly ſhew a manifeſt argillaceous precipitate.

(o) *Nitrated ſilver* diſſolved in diſtilled water affords a moſt complete method of diſcovering the ſmalleſt traces of marine acid; for this acid, whether diſengaged or united with another baſe, inſtantly ſeizes the ſilver, forming with it a metallic ſalt very difficult of ſolution, which therefore ſeparates in the form of a white mucilage. A ſingle grain of common ſalt diſſolved in a kanne of diſtilled water, at the firſt drop of ſolution of ſilver, exhibits white ſtriæ, which, however, are not produced, if the water contains no more than half a grain—but a grain of common ſalt contains about half a grain of marine acid.—Solution of ſilver is acted upon by vitriolic acid far more ſlowly, for no viſible turbidneſs will ariſe, unleſs the kanne of water contains 98 grains of Glauber's ſalt, which contain 25 grains of vitriolic acid. Now, ſince the acid conſtitutes one fourth of ſalited ſilver, we may determine the quantity of marine acid from the weight of the precipitate effected by the ſolution of ſilver when the precipitation is complete.—The quantity of acid contained in vitriolated ſilver is very little greater.

If any hepar be preſent, the ſalited ſilver which precipitates is of a lighter or darker brown colour. It is alſo proper to obſerve, that a ſingle drop of ſolution of ſilver occaſions a viſible precipitation in water altogether deſtitute of both marine and vitriolic acid, provided it contains 12 grains of newly cryſtallized ſal ſodæ to the kanne. Lime and magneſia, united with aerial acid, in like manner precipitate ſilver: but the quantities have not yet been exactly determined.

(P) *Nitrated mercury* is to be employed with great circumſpection, as it poſſeſſes different properties, according to the circumſtances of the ſolution; for if the ſolution has been conducted without heat, very little phlogiſton is loſt, and the ſalt eaſily cryſtallizes, being white, and ſcarcely acrid. This is precipitated, by cauſtic vegetable alkali, of a yellowiſh white: by the ſame alkali, ſaturated with aerial acid, white: by ſal ſodæ, yellow, which ſoon grows white: by volatile alkali, greyiſh black: by Glauber's ſalt, or diſengaged vitriolic acid, white, granulated, and in ſmall quantity; nor, if the precipitant has been ſparingly uſed, does it appear in leſs than an hour: by marine acid, common ſalt, and other ſaline ſubſtances containing that acid, white, in large quantity, and of a caſeous conſiſtence. Solution of mercury, made without heat, immediately diſcovers the marine acid, even although there be no more than half a grain of common ſalt in a kanne of diſtilled water: but it diſcovers vitriolic acid more ſlowly; for about four grains of Glauber's ſalt (that is, one grain of acid) are requiſite in a kanne of water, in order to occaſion a viſible precipitation with the ſame degree of quickneſs.

When neither vitriolic acid nor marine acid is preſent, the mercury is precipitated by alkalis; as alſo by lime or magneſia diſſolved by means of aerial acid.—A ſingle drop of ſolution of mercury forms viſible clouds, although there be no more than ſix grains of newly cryſtallized ſal ſodæ in a kanne of water.

Solution of mercury, made by long continued boiling in ſuperabundant acid, is more dephlogiſticated, as appears from the red vapours which it ſends forth. This ſolution cryſtallizes with more difficulty, and has a very acrid taſte. It is precipitated by vegetable alkali of a browniſh yellow, but by degrees aſſumes a paler yellow tinge; and, if the alkali be fully ſaturated with aerial acid, the precipitate is at firſt of a browniſh yellow, but afterwards becomes of a yellowiſh white. A browniſh yellow powder is precipitated by ſal ſodæ; this powder afterwards grows white. The precipitate occaſioned by volatile alkali is white; that by vitriolic acid, either diſengaged or united with any baſe, yellow; but the precipitate immediately grows white upon the affuſion of a little marine acid. The ſmalleſt quantity of marine acid, either diſengaged or otherwiſe, occaſions a very copious white mucilaginous precipitate.—A blackneſs in the precipitate indicates either the preſence of an hepar, or that the mercury is nearly in its metallic ſtate (*o*).

Mucilage

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(*o*) It ſometimes happens, not only that the precipitate is black, but that there appears upon the ſurface of the liquor a ſhining pellicle, which announces a ſpecies of revivification. When it is conſidered, that ſuch reductions are effected more eſpecially by the volatile alkali, which contains phlogiſton among its conſtituent parts, it would ſeem certain, that the precipitates are ſo much the more coloured, and the nearer reduction, as the liquor itſelf contains or receives from the precipitant more phlogiſton. Profeſſor Bergman furniſhes an additional fact in favour of this opinion, when he obſerves, that volatile alkali produces a precipitate of a dark grey colour, when the ſolution has been made without loſs of phlogiſton; and of a white colour, when red vapours ariſe during ſolution. He, however, eſtabliſhes here an oppoſite principle, viz. the more there remains of phlogiſton in the ſolution, the leſs is the precipitate coloured. Each, therefore, of theſe ſyſtems is inadequate to the explication of the phænomena. We want ſome further knowledge, in order to conciliate them, and to explain why, for inſtance, the ſame ſolution of corroſive ſublimate is precipitated of a yellow colour by lime-water, and of a white by cauſtic volatile alkali.

The author's obſervation is, notwithſtanding, not leſs valuable;

Mucilage is alſo precipitated by nitrated mercury: thus diſtilled water, containing three grains of cherry-gum in the kanne, on the addition of nitrated mercury inſtantly forms white clouds and ſtriæ.

(Q) *Corroſive ſublimate* is alſo in uſe for the examination of waters, eſpecially for the diſcovery of aerated alkali. If a kanne of diſtilled water contains 280 grains of newly cryſtallized ſal ſodæ, a ſingle grain of ſaturated ſolution of corroſive ſublimate immediately produces a reddiſh powder; a ſmall piece of the ſublimate itſelf, added to the water, diſcovers alkali, even better than the ſolution. —The cauſe of the redneſs of this precipitate is explained elſewhere (*p*).

Both lime and magneſia, when aerated, by means of a double elective attraction, precipitate a calx of mercury, though ſlowly.

(R) *Acetated lead* is precipitated in the form of a white powder by the marine acid, either diſ-

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valuable: it may enable us to diſcover why ſolutions of the ſame metal, in the ſame acid, are leſs permanent; why ſolutions of metallic calxes are leſs apt to form depoſitions, when they proceed ſlowly, &c. Mr Maret has already made a very happy application of this obſervation, by ſhewing, in the Dijon courſe of lectures, that his proceſs for precipitating iron in the form of Ethiops martial, by cauſtic volatile alkali, never fails, but when a nitrous ſolution, made by heat, and with red vapours, is employed. Morveau.

(*p*) Treatiſe on the Aerial Acid, § xxi.

engaged or otherwiſe; and this new combination is ſoluble in vinegar, but is not a convenient precipitant, becauſe ſalited lead is alſo ſoluble in a large quantity of water: it is more convenient for diſcovering vitriolic acid, for the precipitate or vitriol of lead, which is in the form of ſmall grains, is ſcarcely ſoluble in water, or even in vinegar. Diſtilled water, containing 118 grains of common ſalt in the kanne, ſhews ſtriæ ſomewhat milky, if a ſmall piece of acetated lead be laid on the ſurface; upon increaſing the quantity of common ſalt, the appearance becomes more remarkable. Nearly the ſame weight (115 grains) of Glauber's ſalt is requiſite, in order to occaſion a viſible ſeparation of vitriol of lead—and hence it would appear, that theſe two acids are almoſt equally diſcoverable by acetated lead; but we muſt obſerve, that in 118 grains of common ſalt, the acid amounts to about 60 grains; whereas, in 115 grains of Glauber's ſalt, the acid is no more than $29\frac{1}{2}$.—Now, as vitriolic acid forms nearly 0,28 of vitriol of lead, we may, from the weight of the vitriol, in ſome degree judge of the quantity of acid, if the water be completely precipitated by the acetated lead. However, when muriatic acid is preſent, which is almoſt always the caſe, the concluſion is rendered inaccurate, on account of the much greater ſolubility of ſalited lead.

Acetated lead ſeems to loſe its acid ſpontaneouſly ly by age; for a piece of it, when old, put into water, remains inſoluble at the bottom.

A brown or black ſediment indicates the preſence of ſulphur in a ſtate of ſolution; alkalis, lime, and magneſia, diſſolved in water by means of aerial acid, alſo precipitate lead, without the preſence of either marine or vitriolic acid. A ſingle drop of ſolution of lead exhibits white ſtriæ, in water containing no more than ſix grains of newly cryſtallized ſal ſodæ to the kanne.

(s) In ſome caſes, *martial vitriol* promiſes to be of uſe. If a cryſtal of this ſalt be put into an ounce phial filled with diſtilled water, the phial immediately well cloſed, and ſet in a cool place, the vitriol is diſſolved, without depoſiting any ochre, unleſs the water has taken up pure air, which very powerfully attracts phlogiſton, and therefore ſeparates a portion of it from the baſe of the vitriol; ſo that the baſe, being calcined, requires more acid than before to ſuſpend it; and if the deficient acid be not added, the iron neceſſarily falls in the form of an ochre. The ſame is evidently ſeen, when the precipitation is effected by means of an alkali; for the ſediment, which is at firſt green, preſerves its colour in a veſſel full and perfectly cloſed, provided the water be deprived of air, but in an open veſſel it ſoon changes to a ferruginous colour; becauſe, even though the water had not contained any air, the external air acts upon the precipitate. When the water does not contain any thing capable of precipitating the vitriol, a few drops of alkaline lixivium may be added before the veſſel is ſhut; but if the water contains air, the alkali is not neceſſary, as the baſe of the vitriol is quickly dephlogiſticated; and hence, as has been before obſerved, the ſame quantity of acid is not ſufficient to diſſolve it, and conſequently ſome ochre is depoſited. If there be preſent at the ſame time a conſiderable quantity of aerial acid, the ochre is rendered white.— The quantity of ochre ſerves in ſome meaſure to determine the quantity of air preſent.

It is alſo neceſſary to obſerve, that not only alkalis, but alſo lime and magneſia, united with aerial, marine, or nitrous air, decompoſe martial vitriol, although a precipitate does not appear in every caſe; for marine acid holds iron ſuſpended, although it be very much dephlogiſticated.

(T) *White arſenic* is only uſeful when water is more or leſs impregnated with hepatic vapour, but does not contain a genuine hepar (x). If to ſuch water a ſmall piece of white arſenic be added, the arſenic grows yellow by attracting the ſulphur, and is thus converted into orpiment.

(U) *Soap* is not ſoluble in every kind of water; this is occaſioned either by a diſengaged acid, or by a large proportion of middle ſalt, with an earthy or metallic baſe; in either caſe a decompoſition takes place, the acid unites with the alkali, and the oil is diſengaged: ſuch waters as theſe are generally called hard waters, and are unfit for waſhing clothes, as alſo for boiling pulſe, and the harder kinds of fleſh.

Diſtilled water ſcarcely takes up 0,1 its own weight of ſoap, and that imperfectly, for it contracts an opal colour; and after ſome time the ſoap, which had been ſuſpended, falls to the bottom in the form of a mucilage. Spirit of wine acts upon ſoap more powerfully, for it takes up more than $\frac{1}{3}$ its own weight, after which it admits without growing turbid, the addition of diſtilled water, but not of hard. If there be preſent in a kanne of water but 8 grains of alum, ſalited magneſia, or ſalited lime, a ſingle drop of this water occaſions a turbidneſs in ſolution of ſoap in alcohol, diluted with an equal bulk of diſtilled water.

(x) Some perſons add to the above-mentioned precipitants *hepar ſulphuris*, becauſe it is decompoſed by the weakeſt acid, and even by the pureſt aerial acid; however, in the examination of waters, we may readily diſpenſe with it, as well as with ſalited lime, alum, corroſive ſublimate, nitrated mercury, (at leaſt that prepared by heat) and acetated lead;—the ſame is true of milk. If to hepar ſulphuris a ſmall quantity of vitriolic acid be added, an elaſtic vapour is immediately generated, with which water may be impregnated in the ſame way as with aerial acid, and it will then poſſeſs the hepatic odour (VIII. E).

(Y) *Alcohol* added in ſufficient quantity precipitates all the ſalts found in waters which are inſoluble in ſpirit of wine. Such are all thoſe containing vitriolic acid, but thoſe conſiſting of marine or nitrous acid are generally ſoluble, but require different quantities of ſpirit for their ſolution (*q*). Here it may be uſeful to remark, that, according to experiments which I have made for the purpoſe, alcohol, in an heat of 15 degrees, can take up, of dry nitrated magneſia, $\frac{1}{10}$ its own weight; of dry ſalited magneſia, $\frac{1}{7}$; of dry nitrated lime, $\frac{1}{7}$; and of dry ſalited lime, $\frac{1}{1}$.

Beſides the precipitants already mentioned, many others have been employed, which, I imagine, we may paſs over untouched, as they diſcover no more than thoſe already propoſed, nor are they more accurate. Nor indeed is it neceſſary to employ the whole of the ſubſtances already examined:—it is true, that when time and circumſtances permit, even ſuperfluous trials are not improper, as they tend to confirm one another; yet, for the moſt part, a few, when well choſen, are ſufficient for the purpoſe.—For the diſcovery of acids, when diſengaged, we have occaſion only for the tincture and paper of turnſole;—when they are united with other ſubſtances, they are eaſily diſcovered by nitrated ſilver and ſalited terra ponderoſa;—uncombined alkalis are detected by the papers tinged with Brazil-wood and tur-

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(*q*) Vid. M. Macquer Exp. in Comm. Taurenſibus.

meric, and when combined with acids they are diſcovered by ſpirit of wine.—Aerated calcareous earths are precipitated by the acid of ſugar; and, when thus completely ſeparated, that ſpecies which can afterwards be thrown down by aerated alkali is either magneſia or clay; the former of which diſſolves in diſtilled vinegar, with effervescence, while the latter is taken up ſlowly, and without any effervescence.—Metals are plainly diſcovered by phlogiſticated alkali, but theſe, iron only excepted, are rarely found in waters; ſo that, for the moſt part, tincture of galls is ſufficient.—If terra ponderoſa be at any time preſent, it is diſcovered by vitriolic acid.—Saline or earthy hepar is very rarely found in the natural cold waters, but may be eaſily decompoſed by any acid whatever; and when the ſulphur, which occaſions a turbidneſs, is ſeparated, the tranſparency returns. In general, water contains only an hepatic vapour, which, though it reſembles hepar in ſmell, is not decompoſed by the addition of any acid, excepting only thoſe which, even though diluted, powerfully attract phlogiſton;—of this kind is the nitrous acid. Beſides, at Aix pure air, out of the water, ſeparates the ſulphur from the hepatic vapour, which, in this inſtance, is not confined by union with an alkali (VIII. E).

Finally, precipitants may be employed, not only with the waters newly taken from the ſpring, but after they have been reduced by evaporation to a ſmall bulk.—If it be only neceſſary to determine the quality of heterogeneous matters, one or two cubic inches of the water, and a few drops of the proper precipitants, will ſuffice; but if we deſire alſo to know the weight of the different ſubſtances, large quantities of water muſt be ſubjected to experiment, and theſe ſhould be conducted in tranſparent glaſs veſſels.

## § VIII. *Method of collecting the heterogeneous volatile Matters.*

The elaſtic vapours, reſembling air, which are more or leſs abundant in waters, have occaſioned conſiderable difficulty in the examination of them; and the method of exactly collecting theſe volatile ſubſtances was unknown until the preſent age: beſides, the methods at firſt employed (ſuch as agitation in a glaſs veſſel, with an empty bladder tied to its neck; or boiling the water, and conducting the vapour into a veſſel filled with water, and inverted) were lame and imperfect;—for, in the former method, the whole of the volatile ingredient can ſcarcely be elicited—and in the latter, no ſmall part of that which is extricated is again concealed, being abſorbed by the water through which it paſſes.

But by the following method, that vapour, commonly known by the name of mineral ſpirit, may, tain all the elaſtic fluid extricated, together with the portion of common air contained in the retort above the ſurface of the water;—its capacity ought therefore to be ſomewhat greater than the ſum of the bulks of the air contained in the retort, and of the water under examination, if the water be ſaturated with elaſtic vapour; but if it be common water, a much leſs ſize will ſuffice.

The whole apparatus being properly prepared, fire muſt be applied, and continued to full ebullition. The heat penetrating the water, occaſions a quantity of bubbles, which, increaſing as the heat increaſes, paſs through the mercury, and are collected in the upper part of the veſſel D E. A few minutes boiling will not indeed be ſufficient to expel all the elaſtic fluid, but the portion remaining will be very ſmall, and of little moment.

After this proceſs, let the height at which the mercury ſtands in the inverted veſſel be noted, and thus we may aſcertain the ſpace apparently empty, in cubic meaſure. If the veſſel D E be cylindrical, and divided into known parts of dimenſion, the bulk of the elaſtic fluid appears barely from inſpection; from hence, ſubducting the bulk of the common air contained in the retort, the bulk of the elaſtic vapour extricated from the water is determined.—If this apparatus be not at hand, a Florence flaſk, or ſome other veſſel of proper ſize, may be uſed, and a bladder, well compreſſed, tied to its neck, to receive the vapour extricated by boiling: but the concluſion in this caſe will be leſs accurate.

Before the retort cools, the bended part of the neck muſt be taken out of the mercury, otherwiſe that metal will gradually fill the retort; for the apparent vacuum over the ſurface of the water is only occupied by a watery vapour, which is reduced to the form of water by cold (r).

(s) The

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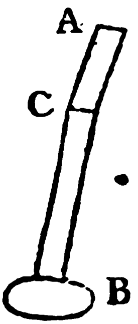
(r) The author here ſuppoſes, that the quantity of mercury diſplaced A C, in the cylindrical receiver here ſketched, indicates the quantity of elaſtic fluid diſengaged by boiling; but this eſtimation is not exact, becauſe the air contained in the ſpace A C is in a greater ſtate of dilatation than the atmoſpherical air; for inſtead of being charged with the whole weight of the atmoſphere, it is only charged with that weight, diminiſhed by the weight of the column of mercury C B; ſo that if the preſent ſtate of the barometer in the open air is expreſſed by H, the height of the column C B by h, the denſity of the air in A C will be to that of the open air, in the proportion of H — h to H. If then the column C B is of ſeven inches, while the barometer ſtands at 28, four meaſures of the air contained in A C would be only equivalent to three, at the degree of condenſation of the open air. Further, the error may be total, *i. e.* by following this method one might be led to believe that there was air in water which contained none at all, becauſe the air remaining in the neck of the retort, dri-



(B) The elaſtic fluid, thus collected, generally conſiſts partly of pure air and partly of aerial acid. To demonſtrate this, and (if both be preſent) to determine the quantity of each, one of them muſt be ſeparated; which is performed in this manner: Let the aeriform fluid be agitated with lime-water, which may be introduced into the inverted veſſel, by cloſing it carefully, and transferring it from the mercury into a veſſel filled with lime-water, and then opening it; by theſe means the aerial acid is abſorbed, and the pure air, if any there be, remains alone—the bulk of which ſubducted from

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ven by the ebullition into A C, will be the more expanded the more the preſſure of the air is diminiſhed, or the higher the column B C happens to be. Attention ſhould therefore be paid to this dilatation, and it may eaſily be aſcertained; for if the volume of air remaining in the retort is called v, the volume of mercury diſplaced in the receiver r, the height of the mercury in the barometer at the time of the operation H, and the height of the column of mercury C B, h, the quantity or bulk of the air really diſengaged from the water by boiling, and reduced to the denſity of the atmoſpherical air, will be $r - e - \frac{r\,h}{H}$. If, for inſtance, three meaſures of air had been left in the retort, and that air had diſplaced four in the receiver, and the column of mercury C B had been 7 inches, and the barometer at 28, the quantity of air produced would be $4 - 3 - \frac{4 \times 7}{28} = 0$. Note, communicated by M. de Sauſſure to M. de Morveau.

the whole ſhews the quantity of aerial acid (*s*).

(c) The aerial acid conſtitutes the genuine *ſpiritus mineralis* of the ancients as is moſt evidently demonſtrated by the analyſis above propoſed; for all the mineral waters celebrated for virtue give out a conſiderable quantity of an elaſtic fluid, (even ſometimes a portion equal in bulk to the water itſelf), poſſeſſing all the properties of that ſubtile acid. And what puts the matter beyond doubt is, that if the elaſtic fluid of ſuch waters be either

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(*s*) Mr Gioanetti is of opinion, that the quantity of aerial acid may be better determined by weight than bulk: his method certainly does not require either an apparatus on purpoſe, or ſo much nicety: he puts into a large bottle two pounds of aerated water, and pours in a ſuberabundant quantity of lime-water, he then corks it; as ſoon as all the precipitate has fallen to the bottom, he ſeparates the liquor by means of a ſyphon, and, having edulcorated and dried the precipitate, eſtimates the weight of the aerial acid by the weight of the calcareous earth. In order to diſtinguiſh the uncombined aerial acid from that which might be united with ſome baſis, he repeats the ſame operation upon water deprived of its air by boiling. Mr Gioanetti aſſumes, for the foundation of his calculation, the experiments of Mr Jacquin; according to which, 32 parts of calcareous earth contain 13 of fixed air, 2 of water, and 17 of earth; but this eſtimation differs from that of Profeſſor Bergman by $\frac{11}{100}$; whence it appears, that it is not leſs difficult to determine with preciſion the quantity of fixed air contained in calcareous earth than the proportion which the bulk of this fluid bears to its weight. See Analyſe des Eaux de St Vincent, p. 14. Morveau.

gradually diſſipated in an open veſſel, or ſuddenly expelled by heat, the water loſes its grateful pungent acidity, which it recovers altogether, when the loſs of that elaſtic fluid is ſupplied: analyſis and ſyntheſis then agree ſo perfectly on this occaſion, that whoever conſiders the operations with due attention muſt be clearly ſatisfied of the truth of the poſition — in another place, I have at large explained the method by which the natural aerated waters may be imitated.

It may happen, indeed, that the phlogiſticated vitriolic acid (commonly called volatile acid of ſulphur) ſhall be mixed with the aerial acid; but moſt undoubtedly this is a very rare occurrence: at leaſt, I do not heſitate to aſſert, that the Pyrmont, the Spa, the Seltzer, and other waters, whoſe penetrating and volatile efficacy has been attributed to a diſengaged phlogiſticated vitriolic acid, do not contain the ſmalleſt particle of it. Theſe waters, upon analyſis, are found to contain lime and magneſia aerated; and the laſt (the Seltzer) alſo contains an aerated mineral alkali, which is utterly incompatible with the exiſtence of a diſengaged vitriolic acid; for this acid, to whatever degree it may be phlogiſticated, attracts lime, magneſia, and alkali, with a force ſuperior to that of the aerial acid: if preſent, therefore, it muſt expel the weaker acid, and take its place—that is, it muſt loſe its diſengaged ſtate. The preſence of phlogiſticated vitriolic acid cannot therefore be aſſerted, ed, without a palpable contradiction, ſo long as any aerated alkaline ſubſtances are found in the ſame water. It is alledged, indeed, that this decompoſition cannot take place in the boſom of the earth, and no doubt (*t*) that is ſometimes the caſe; but it certainly cannot hold with reſpect to Pyrmont, of which, however, it is particularly aſſerted; for, at its very firſt appearance, upon the addition of ſpirit of wine, it ſeparates its magneſia and lime completely vitriolated. No perſon who has ſeen or examined the phlogiſticated vitriolic acid, can poſſibly confound it with the aerial acid; for the ſmell of the former is pungent and highly penetrating, that of the latter ſcarce ſenſible: the taſte of the former, acrid and nauſeous; that of the latter, very mild and agreeable: the former may be reduced to a liquid form; the latter is always in a ſtate of vapour: the former, being ſtronger, expels the latter from every kind of baſe, and forms, with each of them, compound ſalts of a ſpecies very different from thoſe formed by the ſame with aerial (*v*) acid;—in ſhort, they ſcarcely poſſeſs any property in common, excepting only the general properties of acids. If the opinion of ſuch as confound thoſe two acids were well founded, the former would not change the colour of ſyrup of violets, which the latter is never

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(*t*) Aerial Acid, ſee p.

(*v*) Treatiſe on elective Attractions.

found to do; but I have always obſerved that phlogiſticated vitriolic acid, unleſs when mixed with iron, changes ſyrup of violets to a red.

([illegible]) Waters abounding with fixed air, as I before obſerved, poſſeſs a pungent but agreeable aceſcent flavour; and from hence, doubtleſs, it is that from the moſt remote times they have been called *acidulæ*. The propriety of this denomination is called in queſtion by many perſons at this day, becauſe theſe waters effervesce with acids, and not with alkalis; and alſo change the colour of ſyrup of violets to a green; which are conſidered as certain ſigns of an uncombined alkali. But here we muſt obſerve, 1ſt, That, ſtrictly ſpeaking, effervеſcence with acids never indicates a pure alkali, but an alkali united with the aerial acid, which, upon the addition of a more powerful acid, is ſeparated, and, recovering its elaſticity, muſt float in the form of bubbles on the ſurface of the more ponderous fluid; whereas an alkali perfectly cauſtic does not excite the ſmalleſt effervеſcence with acids: 2d, A ſimilar effervеſcence alſo takes place, when lime or magneſia aerated meet with an acid; and this is the caſe with Pyrmont water, which does not contain any aerated alkaline ſalt.—Spa water, indeed, contains a ſmall portion, and Seltzer ſtill more: 3d, Alkaline ſubſtances, whether ſaline or earthy, though ſaturated with aerial acid, yet act as precipitants, in virtue of their alkaline nature, and exert a certain force upon various bodies, which force is not altered by the aerial acid, on account of its extreme weakneſs; this force is, however, ſomewhat diminiſhed, though it can be entirely ſuppreſſed by the quantity of acid neceſſary to the ſaturation of the alkaline ſalt and the water which diſſolves it: 4th, The aerial acid cannot effervefce with alkalis, becauſe it is the expulſion of this acid by a ſtronger one, that occaſions the motion and the ſpumeſcence, appearances which are not occaſioned by the meeting of an alkali with the aerial acid. Thus the moſt completely aerated Pyrmont or Seltzer water, upon the addition of a ſmall quantity of alkaline ſalt, particularly if cauſtic, immediately grows flat, and acquires a vapid taſte, and that without any viſible motion: 5th, The green colour induced upon ſyrup of violets is evidently a fallacious teſt (VII. c); for diſtilled water, in which a ſmall quantity of martial vitriol is diſſolved, poſſeſſes the property of immediately rendering that ſyrup green.

Since, then, in the acidulous waters, not only the alkali is ſaturated with aerial acid, but the water alſo contains it ſo copiouſly as to render tincture of turnſole red, ſuch waters cannot properly be conſidered as alkaline. This acid, though ſuperabundant, is ſo weak, that it is not able totally to repreſs the alkaline properties; it is alſo volatile, but neither its weakneſs, nor its fugacity can ſubvert its eſſential properties.

(E) From the ſulphurated hot waters an hepatic vapour is collected, the preſence of which is readily diſcovered by its peculiar fœtor: this is ſometimes preſent, together with aerial acid diſengaged, and it is decompoſed, when it has quitted the water, by pure air; which cannot appear ſurpriſing, as concentrated nitrous acid is capable of effecting that decompoſition, even in the water. The explanation of both is the ſame: Thus the hepatic aura is tenacious of its form of vapour—hence a very large and dry ſurface of contact is preſented to the atmoſphere, in conſequence of which the pure air ſeizes the phlogiſton, which in a hepatic vapour connects the ſulphur with the matter of heat, and thus, the bond of union being removed, the ſulphur appears in its proper form. This is the origin of the ſulphur which is ſublimed at Aix-la-Chapelle; hence, too, we underſtand how hepatic vapour is quickly decompoſed, and depoſits its ſulphur, upon the addition of any ſubſtance which is capable of ſeparating the phlogiſton.—I before mentioned the conſtituent parts of hepatic vapour; but as this is particularly examined in the Treatiſe on Subterranean Fire, I omit the analytical demonſtration of it here.

(F) The volatile ſalts, which, if I may be allowed the expreſſion, are more corporeal when they happen to be preſent, are found to be driven over into the recipient, or ſometimes, though very rarely, adhering to the neck of the retort, as the watery vapours diſſolve and carry them over; this applies particularly to volatile alkali and the ammoniacal ſalts, which may be eaſily ſeparated by the precipitants deſcribed (§ VII.). Sometimes, however, the water, paſſing over alſo, contains a portion of acid, which, upon examination, is found to be of different ſorts: thus, when nitrated lime or magneſia is preſent, the nitrous acid comes over, becauſe the conſtituent principles of thoſe ſalts cohere ſo looſely, that they are ſeparated by boiling, if continued for any length of time: but the muriatic acid cannot, by this degree of heat, be ſeparated from any ſalt, except ſalited magneſia; the phlogiſticated vitriolic acid may alſo be obtained in this manner, if it be uncombined—the quantities of the ſalts thus decompoſed may be diſcovered by ſaturating the acids reſpectively with baſes of the ſame ſort with thoſe from which they have been expelled. The weight of the new compound indicates the quantity of ſalt decompoſed by the fire.

## § IX. *Method of collecting the fixed heterogeneous Matter.*

During the evaporation of the water, the fixed heterogeneous matters are continually reduced to narrower compaſs, and at length the water becomes inſufficient to retain them all: hence they are ſeparated by degrees, the leaſt ſoluble firſt, and then ſuch as require leſs water for their ſolution. — I ſhall now proceed to deſcribe the method of conducting this operation more particularly.

(A) The veſſels employed ought to be broad, becauſe fluids evaporate more or leſs quickly, in proportion to their ſurfaces. We may ſafely employ for this purpoſe earthen veſſels, provided they are ſo compact as not to abſorb any ſaline matter, with a denſe and ſmooth ſurface, which will not be liable to deſquamation; ſo that ſuch matters as adhere to it during evaporation may be eaſily ſeparated, and ſcraped off pure. Iron and copper are corroded, and therefore are in general altogether unfit for this purpoſe: neither is tin convenient: ſilver, beſides being expenſive, is ſometimes unſafe, eſpecially if there be any uncombined nitrous acid in the water: veſſels made of ſtone ware are excellent in many reſpects, but are liable to two objections: For, firſt, Their ſurface is ſomewhat rough, hence a part of the reſiduum may eaſily be concealed in the holes and inequalities; and, ſecondly, they are ſoft, ſo that ſuch particles as adhere very cloſely cannot be ſcraped off, without danger of ſcraping off alſo a part of the veſſel: glaſs veſſels would be the moſt convenient, if the operations could always be conducted in them without breaking; — ſmall and ſufficiently thin glaſs veſſels may, without danger, be expoſed to an intenſe open fire, if properly regulated; but ſuch as are neceſſary for containing large quantities require for that purpoſe a ſufficient degree of thickneſs; and hence, being unfit to endure ſudden changes of heat and cold, are eaſily broken. The ſize of the veſſels depends upon the quantity of water neceſſary for the ſeveral experiments.

(B) The quantity of water neceſſary to be ſubjected at one time to experiment is generally determined by the quantity of heterogeneous contents; if theſe are abundant, one kanne is ſufficient; but when the quantity is ſmall, ſix, eight, or more are requiſite. If our veſſels are not of ſize ſufficient to contain the whole quantity at once, we muſt add the water from time to time, according as room is made by the evaporation; but this muſt be done with great circumſpection, leſt the warm veſſel ſhould be broken by the coldneſs of the water.

(C) A gentle evaporation is moſt proper; for by violent ebullition a portion of the ingredients is diſſipated, nay ſometimes decompoſed. A cover is neceſſary, to keep out the charcoal, duſt, and embers; this cover muſt give exit to the vapours by an hole ſeveral inches in diameter; but the hole ſhould be kept ſhut until the iſſuing vapour is ſo far condenſed as to prevent the duſt from falling in.

(D) In this proceſs different phenomena appear, according to the different contents of the water. If there be preſent lime and iron aerated, in an intenſe degree of heat, ſuch as 80° or 90°, they are deprived of the quantity of aerial acid neceſſary to render them ſoluble; they collect, therefore, on the ſurface, where the volatile menſtruum firſt becomes deficient, and form a pellicle, which being broken by the agitation of the water, falls to the bottom when the motion ceaſes. This happens becauſe lime and iron, when barely ſaturated with aerial acid, refuſe to unite with water, but may be taken up when this ſubtile menſtruum is ſuperabundant in the water. This ſuperabundance adheres to them but ſlightly, and therefore flies off during evaporation;—which alſo happens ſpontaneouſly, upon keeping the water for ſome days in an open veſſel.

The above-mentioned pellicle is found whole, when formed by iron; and in this caſe it is tinged with the different priſmatic colours, according to the different points of view. It has been thought that this contained a certain bituminous oil, particularly becauſe it detonates with nitre; but not the ſmalleſt particle of this unctuous matter has as yet been diſcovered in it. As to the detonation, that is occaſioned, in the preſent caſe, by the phlogiſton remaining in the martial earth, which when freſh contains ſo much of that principle, that it is ſoluble in all acids.—But this remainder of phlogiſton is gradually diſſipated, and that the more quickly, and in proportion as it has been expoſed to the more heat during evaporation, and to the more free acceſs of atmoſpheric air. The ſimultaneous variation of colour indicates nothing more than various degrees of tenuity, or various ſtates of dephlogiſtication in the particles.

If aerated magneſia be preſent in water, it is not ſeparated all at once, but continues to fall by degrees during the whole proceſs, from the beginning of the evaporation even to dryneſs.

Aerated lime and ſiliceous particles fall rather before a boiling heat.

Of all the ſalts, gypſum falls firſt, but not until long after aerated lime and aerated iron.

If ſaturated ſolutions of different ſalts be mixed, they all appear, during the evaporation, in an order conformable to their degree of ſolubility; that is, ſuch as are leaſt ſoluble in water appear firſt:—thus, alum is the foremoſt, then vitriolated vegetable alkali (if any there be) afterwards, in order, martial vitriol, common nitre, vitriol of copper, ſalited vegetable alkali, mineral alkali, common ſalt, vitriol of zinc, vitriolated magneſia, and, laſtly, the deliqueſcent ſalts: but this order is frequently interrupted by the quantity of the diſſolved matters.

The different heterogeneous matters may accordingly be either ſeparated as they ſucceſſively appear, or, by continuing the evaporation to dryneſs, be obtained all mixed together. The former method is in ſome inſtances ſufficiently commodious, but is generally of little uſe, eſpecially when aerated magneſia is preſent, as this ſubſtance does not ſeparate altogether; beſides, the ſalts, however carefully collected in this way, are more or leſs mixed with each other, and the deliqueſcent ſalts occaſion much inconvenience, eſpecially about the end of the operation. If every particular ingredient is to be ſeparately and accurately collected, the water muſt be frequently filtered, a proceſs which is attended with as much trouble as the repeated ſolution and evaporation of the reſiduum, but is much more uncertain, on account of the particles which are loſt upon the filter—hence the latter method appears to be more eligible. If circumſtances permit us to repeat our analyſis, the former method may be tried, for the ſake of compariſon.

(k.) The evaporation being continued to dryneſs, the whole reſiduum ſhould be carefully collected, and, if thought neceſſary, weighed; but the weight of the whole will be more accurately determined from the ſum of the ſeveral ingredients; becauſe, on account of the inequality of exſiccation, more or leſs of the water of cryſtallization may be expelled.—Such ſalts as can be reduced to the form of cryſtals ſhould be weighed when in that form.

## § X. *Examination of the Reſiduum not ſoluble in Water.*

(A) The whole reſiduum, well dried, is then put into a bottle, and alcohol poured over it, to the height of an inch; the veſſel is then ſhut cloſe, and ſhaken; and, after ſtanding for a few hours, the liquor is filtered.

(B) To the reſiduum is then added eight times the quantity of cold diſtilled water; the mixture ſhaken; and, after ſtanding ſome time, it is filtered.

(C) Finally, the reſiduum is boiled for a quarter of an hour in ſomewhat more than four or five hundred times its weight of diſtilled water, and afterwards filtered.

(D) The reſiduum now is not ſoluble, either in ſpirit of wine or water. If it abounds in particles of iron, let it be expoſed in an open veſſel for ſome weeks to the rays of the ſun, and moiſtened from time to time: by theſe means the metal is ſo much dephlogiſticated, that it is not ſoluble in vinegar, (an effect which may be produced in a ſhorter time, by means of heat), but at the ſame time the magneſia is calcined, and the weight ſuffers a (*u*) diminution. The preſence of iron is very eaſily diſcovered by the brown colour. The

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(*u*) Diſſ. on Aerial Acid.

ſlow calcination by the ſun's rays occaſions no inconvenience; for the reſiduum being dry, a traveller may eaſily carry it with him where-ever his occaſions lead him.

The reſiduum generally conſiſts of three or more ingredients mixed together; theſe may be ſeparated from each other by the following method:—1ſt, Upon this reſiduum, previouſly calcined, if neceſſary, and weighed, is poured diſtilled vinegar, which, by digeſtion, diſſolves the aerated lime and magneſia remaining in the reſiduum. Any mineral acid may be employed for this purpoſe, if there be no iron preſent, a circumſtance which ought to be previouſly examined by the colour and by the precipitants above deſcribed; but as there is ſometimes preſent an argillaceous matter, which is more eaſily taken up by the mineral acids, I rather recommend the uſe of diſtilled vinegar. The reſiduum, which is not taken up by the vinegar, when waſhed and dried, ſhews, by its loſs of weight, how much has been diſſolved.

2dly, The acetous ſolution, evaporated to dryneſs, yields acetated lime, filamentous, and reſembling moſs. This ſubſtance is permanent in a moiſt air, if it only conſiſts of lime; but deliqueſcent, if it contains magneſia. This point may alſo be further aſcertained by diluted vitriolic acid, (which, to guard againſt ſuperabundance, ſhould be dropped in ſparingly and ſlowly); for this acid, in the former caſe, converts the whole maſs into gypſum, which falls to the bottom and is nearly void of taſte; but in the latter, it diſſolves the magneſia perfectly, forming vitriolated magneſia extremely bitter, and which, on evaporation, forms priſmatic cryſtals; or, if the baſe be mixed, it forms partly gypſum, partly vitriolated magneſia.

3dly, In order to know the weight of ſoluble earth which had been ſuſpended in the water, let the gypſum and vitriolated magneſia be ſeparately diſſolved, precipitated by an aerated alkali, waſhed, dried, and weighed; but this tedious proceſs may be avoided, if we recollect that 100 parts of gypſum contain about 34 of pure lime, which are equivalent to nearly 61 of aerated lime; and that 100 parts of vitriolated magneſia contain 19 of pure magneſia, which are equal to 42 of aerated magneſia.

4thly, That part which is not ſoluble in the vinegar, is either argillaceous, martial, or ſiliceous. The preſence of the firſt always renders the water ſomewhat turbid, and of an opal colour: this, as well as the martial earth, is ſoluble in marine acid; but the metallic earth may be precipitated alone by a phlogiſticated alkali; after which the argillaceous part may be thrown down by an alkali. Such portion as reſiſts a ſufficient quantity of marine acid, is ſiliceous earth, which may be further determined by the blow-pipe; for this earth, when added to the mineral alkali in fuſion, unites with it, with a violent efferveſcence, and is thereby totally diſſolved (*e*).

5thly, Aerated manganeſe may, perhaps, ſometimes be diſcovered in waters; in which caſe it is found in the reſiduum, N° 4, and may be ſeparated in the following manner:—Firſt let the reſiduum be violently calcined, then pour upon it diluted nitrous acid, with the addition of a little ſugar; and, after ſtanding for about an hour, let the liquor be filtered. Upon dropping an alkali into the filtered liquor, a white powder falls, which by ignition grows black, and the weight of which is to be determined by the balance. The rationale of this operation will readily appear (*f*) hereafter; I therefore paſs it over here, in order to avoid repetition as much as poſſible.

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(*e*) Mr Gioanetti (l. c. p. 22.) is of opinion, that the quantity of iron may be determined by precipitation with galls; he pours in the infuſion till there is a ſuperabundant quantity; and he afterwards expoſes the precipitate to heat in a luted crucible;—it loſes about ¼ of its weight, and becomes ſenſible to the magnet. This proceſs may be uſeful to verify or compare reſults, but alone is not ſufficient, as it affords no indication of the ſtate of the iron, nor of the menſtruum. Beſides, the great diminution of the precipitate after calcination, does not allow us to ſuppoſe that its magnetic properties are deſtroyed by exceſs of phlogiſton. Morveau.

(*f*) Of the white Ores of Iron.

6thly, If at any time aerated terra ponderoſa is contained in the reſiduum, (which certainly may be the caſe, although no perſon has hitherto diſcovered it), it diſſolves in vinegar like the other abſorbent earths, and differs from lime in this particular, that it forms, with vitriolic acid, a ſpathum ponderoſum, which is not ſoluble in a thouſand times its weight of water. 100 parts of this ſpar contain about 84 of pure terra ponderoſa, which are nearly equivalent to 130 of that earth when aerated.

## § XI. *Examination of the Reſiduum ſoluble in Water.*

We ſhall now proceed to examine the ſolutions mentioned in the preceding ſection.

(A) The ſolution obtained by alcohol (X. A) contains chiefly lime and magneſia ſalited, lime and magneſia nitrated, together with ſalited terra ponderoſa, if one or more of theſe ſubſtances be contained in the water. In order to diſcover the quality and quantity of the ingredients, evaporate to dryneſs, pour on diluted vitriolic acid, and continue the proceſs as deſcribed (X. D, 2, 3.). Sometimes the alcohol alſo contains a dephlogiſticated martial vitriol, which may be ſeparated from the ſolution, diluted with a ſufficient quantity of water, by a phlogiſticated alkali. The ſolution is of a reddiſh brown.

(B) The ſolution made by cold water (X. B.) is to be thus examined: 1ſt, Cryſtallization is to be attempted by gentle evaporation—this cryſtallization ſucceeds better when the deliqueſcent ſalts are ſeparated. Excepting common ſalt, (of which cold water diſſolves nearly as much as hot, and which therefore is cryſtallized by continual evaporation), all the ſalts eaſily aſſume regular forms, if the evaporation be carried on in a heat of 80° or 90°, until a drop of the ſolution let fall upon a cold glaſs, in the ſpace of a minute, exhibits cryſtalline grains or ſpiculæ. Slow refrigeration is alſo preferable to a quick one. Evaporation conducted with a boiling heat, will ſometimes produce perfect cryſtals on the ſurface; but theſe generally conſiſt of an aggregation of various ſorts. When we are only inquiring into the ſpecies of the ſalt, and not its figure, we muſt proceed in another way: —

Let the cryſtals which ſucceſſively appear be put upon bibulous paper and dried, but not ſo much as to expel any of the water of cryſtallization: the form, taſte, and other qualities, mentioned in D, will in ſome meaſure ſerve to determine the true nature of each ſalt; but in order to avoid the ſmalleſt doubt, we ſhall conſider them all in the following manner: in No 2. alkaline ſalts alone are comprehended; 3. neutral ſalts; 4. earthy ſalts; 5. metallic ſalts; and, finally, 6. a number of mixed ſalts, which are ſeparated with more difficulty.

2. Whether any given ſalt be alkaline or not, may be diſcovered to a certainty by various methods; viz. by its lixivious taſte, effervescence with acids, and the various precipitants (VII. B. C). By uniting it with vitriolic (*g*) acid, we may determine the ſpecies of alkali.

Authors ſpeak of a certain imperfect mineral alkali; but all of that ſort, which I have had an opportunity of ſeeing, appear to be no other than a genuine alkali, but impure, particularly vitiated by deliqueſcent ſalts. But we ſhall have occaſion, perhaps, to ſay more of this hereafter.

3. I call thoſe ſalts *neutral*, which are compoſed of an acid and an alkali; and I call thoſe *middle* ſalts, which have not a ſaline, but an earthy, or metallic baſe. Perfect neutral ſalts, ſuch as are found in water, do not ſhew any ſigns either of acid or alkali in a diſengaged ſtate, nor are ſolutions of them rendered in the leaſt turbid on the addition of an alkaline ſalt.

In the examination of either neutral or middle ſalts, two circumſtances muſt be particularly attended to; namely, 1ſt, to determine what the conſtituent acid is; and 2d, what baſe the acid is united with.—Vitriolic acid is diſcovered

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(*g*) Diſtilled vinegar is preferable, as it forms, with vegetable alkali, a deliqueſcent ſalt, and with the foſſil a foliated cryſtallizable ſalt. Morveau.

vered by ſalited terra ponderoſa (VII. F, L) or by acetated lead (VII. R). When the nitrous acid is preſent, it is expelled by the affuſion of concentrated vitriolic acid, and may be diſtinguiſhed by its peculiar ſmell, and its red ſmoke. In like manner, marine acid yields to the vitriolic; but has a different kind of ſmell, and a grey ſmoke. When theſe acids are only in very ſmall quantity, the ſmoke will ſcarcely be viſible in a dry place; but in this caſe the very ſlighteſt veſtige of nitrous acid is made apparent, by expoſing to the fume a paper moiſtened with volatile alkali. To diſcover the moſt minute quantity of marine acid vapour, nothing more is neceſſary than a paper moiſtened with water: the vapour inſtantly ſurrounds this paper, in the ſame manner as the nitrous vapour attaches itſelf to the paper impregnated with volatile alkali.

Beſides, nitrous acid is diſcoverable by detonation; and the marine, by various means, ſuch as nitrated ſilver (VII. O), nitrated mercury (VII. P.), and acetated lead (VII. R).

It is ſomewhat more difficult to diſcover the baſes; the vegetable alkali cannot be ſeparated in the humid way, unleſs by terra ponderoſa; but this ſeparation may be effected in various ways, by means of a double elective attraction (*h*). The mineral alkali is expelled by the vegetable, but in

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(*h*) On elective Attractions.

this caſe does not manifeſt itſelf by turbidneſs (*i*); yet it may be diſcovered by cryſtallization. Both the fixed alkalis expel the volatile, with a peculiar pungent odour.

Vitriolated mineral alkali ſhould be carefully diſtinguiſhed from the combination of vitriolic acid with magneſia. Theſe two ſalts agree in forming bitter priſmatic cryſtals, which ſuffer ſpontaneous calcination in a dry air; but the cryſtals of the former are generally larger, much depreſſed, with a cooler and milder taſte; but they may very eaſily, and inſtantly, be diſtinguiſhed from each other, by the addition of a ſmall piece of each to lime-water; for the lime-water is not rendered in the leaſt turbid by the vitriolated mineral alkali, but the vitriolated magneſia is inſtantly decompoſed; for in this laſt caſe the acid unites with the lime, and forms a gypſum, which together with the deſerted magneſia, is found at the bottom. If theſe, mixed together, be preſent in water, they cannot be completely ſeparated by cryſtallization. I determine the quantity of each in the following manner: I gradually precipitate the magneſia by a ſolution of mineral alkali; I unite this again with vitriolic acid, and obtain, by cryſtallization, a vitriolated magneſia; the weight of which, ſubducted from the whole maſs of ſaline matter, previouſly cryſtallized and weighed,

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(*i*) Ibid. § VII. ſub initio.

yields the weight of the vitriolated mineral alkali. The ſame may be collected from the weight of the precipitated magneſia alone, if we know the proportions of the principles which conſtitute the two ſalts. Authors ſpeak of many varieties of vitriolated mineral alkali, and vitriolated magneſia, varieties which, however, depend entirely upon the difference of purity: thus the ſal Anglicus, Epſom ſalt, Leydſchutz ſalt, Seidlitz, and others, when well depurated, all yield the very ſame vitriolated magneſia.

The vegetable and mineral alkali, when united with marine acid, form ſalts which agree in their cubic figure, decrepitation in the fire, and to a certain degree in their taſte; yet the former is ſomewhat more acrid, and is beſides perfectly diſtinguiſhable by another property, for if into a ſaturated ſolution of this ſalt be dropped the acid of tartar, a pure and genuine tartar falls to the bottom; this does not take place in a ſolution of common ſalt, becauſe the mineral alkali has far leſs affinity with acid of tartar than the vegetable alkali has.

4. If the baſe of the ſalt be earthy, which is known by its precipitating on the addition of aerated alkali, the ſpecies of the earth may be thus determined:—terra ponderoſa produces, with the vitriolic acid, a ſpathum ponderoſum (x. D, 6.); calcareous earth, with the ſame acid, produces a gypſum (x. D, 2.); magneſia, the ſalt commonly

called ſal catharticus amarus (X. D, 2.); and clay produces alum.

5. If any metal be preſent, it may generally be known by the colour, or by an ochre.—If the baſe be cupreous it is precipitated in a metallic form upon iron, if the moiſtened ſalt be rubbed upon the metal, or a poliſhed piece of iron laid in the ſolution; it is diſcoverable alſo by a blue colour, an æruginous taſte, by the volatile (VII. I), or by the phlogiſticated alkali (VII. E).

*Iron* is detected by its colour, which is greeniſh, or yellowiſh, according to the degree of dephlogiſtication, by its inky taſte, by an ochre, by tincture of galls (VII. D), and by phlogiſticated alkali, which precipitates a Pruſſian blue (VII. E).—In the Treatiſe on Alum, I ſhall explain at large the method by which martial vitriol may be ſeparated from vitriolated magneſia and alum.

*Zinc* forms, with vitriolic acid, a white vitriol, of which the cryſtals have a priſmatic figure.—This metal is precipitated white by alkalis; as alſo by the phlogiſticated alkali; but is not at all affected by any metal.

*Manganeſe* alſo yields a white vitriol and white precipitates; but it differs from zinc in growing black by calcination, and being afterwards inſoluble in acids, unleſs they are either themſelves phlogiſticated, or rendered ſo by the addition of ſome ſuitable ſubſtance, ſuch *v. g.* as ſugar.

*Arſenic*, in its reguline form, is not ſoluble in water; and of the white calx of arſenic, cold water takes up no more than a few grains in a kanne; —beſides, this calx is very rarely found naturally ſoluble in water; nevertheleſs, as it may ſometimes happen, eſpecially in countries abounding with metals, that water ſhall be vitiated by arſenic, I ſhall here ſhew by what method it may be diſcovered.

If the dry reſiduum be thrown upon live coals, or, which is better, expoſed upon a piece of charcoal to flame, by means of a blow-pipe, a ſmell like that of garlic will be diſtinctly perceived;—this is the moſt certain indication of the preſence of arſenic. Many other methods have alſo been thought of, but they are in general ſuch as cannot be employed unleſs the water contains arſenic alone, which is ſeldom or never the caſe.—If a clear ſolution of hepar ſulphuris be dropped into water containing arſenic, and no ſubſtance be preſent to prevent it, a yellow precipitate immediately falls, which is found to be a ſpecies of orpiment or ſulphurated arſenic.

6. The various ſalts, although very different from each other, when once mixed together, are not eaſily ſeparated; hence often ariſes conſiderable difficulty in the analyſis of waters; for certain of the neutral and middle ſalts, enter into more compound combinations, and obſtinately reſiſt ſeparation, even though cryſtallization be many times repeated; at leaſt they adulterate one another,

ther, and are not obtained pure without the utmoſt difficulty.

This difficulty has already been in ſome degree removed by ſeparating the deliqueſcent ſalts (X. A), which otherwiſe would enter the water neceſſary for cryſtallization, and prevent that proceſs from going on regularly.—The following are the principal inconveniences which ſtill remain:—

The uncombined mineral alkali can ſcarce be perfectly ſeparated from common ſalt: the weight of both theſe taken together being known, let the alkali by degrees be exactly ſaturated with vitriolic acid; this being done, let an equal quantity of the ſame acid be ſaturated with mineral alkali; which being cryſtallized, the weight of alkaline ſalt mixed with the common ſalt, and conſequently the weight of the ſea-ſalt itſelf, will appear (*k*).

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(*k*) As the operator can never be ſure of attaining the preciſe point of ſaturation, even though he ſhould uſe the precautions of diluting the acid or alkali, and mixing a tincture with the liquor; that he may be able to perceive the progreſs of its changes, the proceſs of M. Gioanetti to obtain the ſeparations of the ſame ſalts ſeems more advantageous; it conſiſts in reducing all the foſſil alkali into foliated earth, by the addition of a ſufficient quantity of diſtilled vinegar; and, after cryſtallizing the whole maſs again, to diſſolve the terra foliata in ſpirit of wine: the ſole attention neceſſary is, not to burn the terra foliata, and conſequently to evaporate by a very gentle heat. The learned phyſician of Turin found that ſpirit of wine would not take up ſea-ſalt, even when mixed with terra foliata.

We have already ſhewn (B. 3.) how mineral alkali and magneſia, when united with the ſame vitriolic acid, as alſo vegetable and mineral alkali, when ſalited, may be ſeparated;—the weight of the whole and of one ingredient being known, that of the other is eaſily determined.

Alum and vitriolated magneſia are ſeparated by chalk, but not by quick lime, which decompoſes both; whereas chalk, or rather aerated lime, decompoſes alum, but induces no change upon vitriolated magneſia.

Finally, if diſtinct concretions cannot otherwiſe be obtained, the metallic ſalts are to be precipitated by phlogiſticated alkali, the earthy ones by fixed alkali, and the precipitates managed as directed (X. D): the quantities of the precipitating alkalis, and of the ſalts produced by their means, cannot fail to give the requiſite information (D).

(C) The ſolution made by boiling water (X. C) contains ſcarcely any thing more than gypſum, which may be either ſeparated by cryſtallization, or decompoſed by an alkali.

(D) In order that the different ſalts may be the more eaſily diſtinguiſhed, and their mutual rela-

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By diſtilling the ſpirit of wine, and calcining the reſiduum, the foſſil alkali which exiſted in the firſt ſaline maſs will be retrieved in ſubſtance without mixture. The quantities then may be verified in this caſe, both by ſubtraction and addition, and by procuring the matter itſelf. Morveau.

tions the better underſtood, I add the following ſketch of the moſt remarkable among them, having treated elſewhere of the aerated alkalis.

### *Vitriolated vegetable Alkali;* vulgo *vitriolated Tartar.*

(*l*) 100 parts contain about 52 of pure vegetable alkali, 40 of vitriolic acid, and 8 of water. In an heat of 15° one part of this ſalt requires, for ſolution, 16 of water, but of boiling water no more than 5. The taſte is weak and ſomewhat bitter; it does not deliqueſce in a moiſt, nor ſuffer ſpontaneous calcination in a dry air; it decrepitates in the fire, and is fuſed with difficulty.

The original form of the cryſtals is that of an

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(*l*) I ſhall ſubjoin Mr Kirwan's eſtimation of the reſpective quantity of ingredients in theſe ſaline compounds. The reader will probably be ſurpriſed at the difference between his numbers and thoſe of the author; but ſuch problems are among the moſt difficult in chymiſtry. There is, however, a circumſtance which muſt not be concealed, and which will contribute to reconcile much of the difference:—Mr Kirwan conſiders the acids as pure, and totally free from water; whereas Profeſſor Bergman conſiders them in a ſtate of conſiderable concentration indeed, but as containing a very large proportion of water.

100 grains of this ſalt, perfectly dry, contain, according to Mr Kirwan, 30, 21 of real acid, 64, 61 of alkali, and 5, 18 of water: when cryſtallized, they contain 6, 18 of water. B.

hexagonal

hexagonal priſm, terminated at both ends by an hexaedral pyramid.—The accidental figure varies in many different ways.

## *Vitriolated mineral Alkali;* vulgo *Glauber's Salt.*

(*m*) 100 parts contain 15 of pure mineral alkali, 27 of vitriolic acid, and 58 of water. In a moderate heat, one part requires $2\frac{6}{7}$, of water, of boiling water only $\frac{4}{3}$.—It does not deliqueſce in a moiſt air; it ſuffers ſpontaneous calcination in heat; it liquefies in the fire, again grows dry, and then fuſes.—The taſte, bitter and cold.

The form irregular hexagonal priſms; two oppoſite ſides broader, the apices oblique, formed of two planes, conſiſting of the two oppoſite narrow ſides of the priſm, inclined to each other in a manner reſembling the roof of an houſe.

## *Nitrated vegetable Alkali;* vulgo *common Nitre.*

(*n*) 100 parts contain 49 of pure vegetable al-

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(*m*) 100 grains, perfectly dry, contain 29, 12 of mere vitriolic acid, 48, 6 of mere alkali, and 22, 28 of water. —In cryſtals they contain 13, 19 of vitriolic acid, 21, 87 of alkali, and 64, 94 of water. B.

(*n*) 100 grains, perfectly dry, contain 30, 86 of acid, 66 of alkali, and 3, 14 of water.—In cryſtals they contain 29, 89 of acid, 63, 97 of alkali, and 6, 14 of water. B.

kali, 33 of nitrous acid, and 18 of water; one part requires 7 of water, but of boiling water ſcarce more than 1. The taſte, acrid, bitteriſh, cold;—it neither deliqueſces nor effloreſces;—it detonates with ignited phlogiſton.

The form priſmatic, hexagonal, often ſtriated. The apices hexagonal, pyramidal, generally obliquely truncated.

*Salited vegetable Alkali*; vulgo *Sal digeſtivus Sylvii.*

(*o*) 100 parts contain 61 of pure vegetable alkali, 31 of marine acid, and 8 of water; 1 part requires, for ſolution, 3 parts of water in a moderate temperature; of boiling water 2. The taſte, ſalt and acrid; it neither ſuffers deliqueſcence, nor ſpontaneous calcination; it decrepitates in the fire, and fuſes.

The form cubic, ſometimes priſmatic, quadrangular, perpendicularly truncated.

*Salited mineral Alkali;* vulgo *Sea Salt*, or *Muria.*

(*p*) 100 parts contain 42 of pure mineral alkali,

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(*o*) 100 grains, perfectly dry, contain 29, 68 of acid, 63, 47 of alkali, and 6, 14 of water; but when cryſtallized they contain 7, 85 of water. B.

(*p*) 100 grains, perfectly dry, contain nearly 35 of real acid, 53 of alkali, and 13 of water. 100 grains of the kali, 52 of marine acid, and 6 of water. One part in a moderate heat requires $2\frac{14}{17}$ of water, of boiling water $2\frac{13}{17}$. The taſte, ſalt.—It ſuffers neither deliqueſcence nor ſpontaneous calcination; it decrepitates in the fire, then flows.

The form cubic.

### *Vitriolated Lime;* vulgo *Gypſum.*

(*q*) 100 parts contain 32 of pure lime, 46 of vitriolic acid, and 22 of water. One part requires of water at a moderate heat 500, of boiling water 450. The taſte, earthy, ſcarcely ſenſible. It ſplits in the fire; and in a very intenſe heat it fuſes.

The form ſpathaceous or octaedral; the two oppoſite apices deeply truncated, ſo as to reſemble a table with a cuneiform margin.

### *Vitriolated Magneſia;* vulgo *Sal catharticus amarus—Epſom Salt.*

(*r*) 100 parts contain 19 of pure magneſia, 33 of

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cryſtals contain 33, 3 of acid, 50 of alkali, and 16, 7 of water. B.

(*q*) The proportion of ingredients in natural gypſum varies, but of artificial 100 grains are eſtimated, by Mr Kirwan, to contain 32 of earth, 29,44 of acid, and 38,56 of water; when well dried it loſes about 24 of water, and therefore contains 42 of earth, 39 of acid, and 19 of water, *per cent.* B.

(*r*) 100 grains, perfectly dry, contain 45, 67 of mere vitriolic of vitriolic acid, and 48 of water. One part requires 1 of water at a moderate heat, of boiling water ſcarce $\frac{2}{3}$. The taſte exceſſively bitter, and ſomewhat cold; it ſuffers ſpontaneous calcination in heat; in the fire it foams, grows dry, and fuſes.

The form priſmatic, tetragonal, with pyramidal quadrangular apices.

### *Vitriolated Clay;* vulgo *Alum.*

(*s*) 100 parts contain 18 of clay, 38 of vitriolic acid, and 44 of water; 1 part requires 30 of water in a moderate heat, of boiling water $\frac{3}{4}$. The taſte ſweetiſh, aſtringent; it ſuffers neither deliqueſcence nor calcination; in the fire it foams, dries, and grows hard.

The form octaedral.

### *Nitrated Lime.*

(*t*) 100 parts, well dried, contain 32 of pure

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vitriolic acid, 36, 54 of pure earth, and 17, 83 of water: in cryſtals they contain 23, 75 of acid, 19 of earth, and 57, 25 of water. B.

(*s*) 100 grains, perfectly dry, contain 42, 74 of acid, 32, 14 of earth, and 25, 02 of water; in cryſtals they contain 23, 94 of acid, 18 of earth, and 58, 06 of water. B.

(*t*) 100 grains, carefully dried, contain 33, 28 of acid, 32 of earth, and 34, 72 of water. B.

lime; the water is not eaſily aſcertained, as a part of the acid is alſo expelled by calcination; it is probable that it amounts to 25 at leaſt, and if ſo, the acid will be 43: it deliqueſces. The taſte extremely bitter and acrid; alcohol diſſolves it, and by ebullition takes up its own weight: it cannot be reduced to the form of permanent cryſtals.

### *Nitrated Magneſia.*

(*v*) 100 parts, well exſiccated, contain 27 of pure magneſia; ſetting down the water at 30, which in this caſe it rather ſeems to exceed, the acid will amount to 43: it deliqueſces, yet may be obtained in the form of oblique, truncated, tetragonal, priſmatic cryſtals; but they ſoon again deliquiate: the taſte, extremely bitter, acrid: 1 part in a moderate heat requires, for ſolution, 9 parts of alcohol.

### *Salited Lime*; vulgo *Fixed Sal Ammoniac.*

(*u*) 100 parts, well exſiccated, contain 44 of pure lime; ſuppoſing the water to be 25, the marine acid will be 31: it deliqueſces, and cannot be reduced to permanent cryſtals. The taſte ex-

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(*v*) 100 grains, well dried, contain 35, 64 of acid, 27 of pure earth, and 37, 36 of water. B.

(*u*) 100 grains, well dried, contain 42, 56 of acid, 38 of earth, and 19, 44 of water. B.

tremely bitter: boiling ſpirit of wine diſſolves its own weight of this ſalt.

### *Salited Magneſia.*

(*w*) 100 parts, well exſiccated, contain 41 of pure magneſia; ſuppoſing the water to be 25, the marine acid will be 34; in deliqueſcing it attracts 0,66 of water: 1 part in a moderate heat requires 5 parts of alcohol: The taſte extremely bitter.

### (*x*) *Vitriolated Copper;* vulgo *blue Vitriol.*

100 parts, cryſtallized, contain 26 of copper, 46 of vitriolic acid, and 28 of water. The taſte aceſcent, æruginous, cauſtic; it calcines in heat: 1 part, in a moderate heat, requires nearly 4 of water, but of boiling water much leſs.

The figure compreſſed, hexagonal, priſmatic, obliquely and parallelly truncated on both ſides.

### *Vitriolated Iron;* vulgo *green Vitriol.*

(*y*) 100 parts contain 23 of iron, 39 of vitrio-

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(*w*) Of this ſalt Mr Kirwan affirms, that it cannot be tolerably dried, without loſing much of its acid, together with the water. B.

(*x*) 100 grains contain 27 of copper, 30 of acid, and 43 of water; of which it loſes about 28 by evaporation, or ſlight calcination. B.

(*y*) 100 grains of this ſalt, in cryſtals, contain 25 of iron, 20 of real acid, and 55 of water. B.

lic acid, and 38 of water: in moderate heat, 1 part requires 6 of water, of boiling water $\frac{3}{4}$; in heat it ſplits into a yellow powder, in the fire, into a ferruginous powder. The taſte aceſcent, ſtyptic, cauſtic.

The form, ſpathaceous: when dephlogiſticated it depoſits a portion of calcined iron; the ferruginous deliqueſcent reſiduum is readily taken up by ſpirit of wine.

### *Vitriolated Zinc;* vulgo *white Vitriol.*

(z) 100 parts contain 20 of zinc, 40 of vitriolic acid, and 40 of water; in a moderate heat, 1 part requires more than 2 of water, but much leſs of boiling water. The taſte aceſcent, aſtringent, cauſtic.

The form, tetragonal priſmatic, terminated by tetragonal pyramidal apices.

The advantage of knowing the proportion of the conſtituent principles is ſignal and extenſive; thus, for example, ſuppoſe the weight of the magneſia precipitated (B, 3) to be equal m, then $\frac{33}{19}$ : $\frac{45}{100}$ m = quantity of vitriolic acid neceſſary for ſaturating it; and $\frac{45}{19}$ m = vitriolated magneſia ariſing from thence — $\frac{33}{27}$ : $\frac{45}{19}$ m, indicates the weight of that vitriolated mineral alkali, which is produced by precipitating the vitriolated magneſia by means of mineral alkali — $\frac{85}{37} : \frac{33}{19} : \frac{45}{100} =$ the pure mineral alkali neceſſary for that precipitation; and $\frac{45}{100} : \frac{15}{37} : \frac{33}{19}\, m =$ the aerated alkali neceſſary for the ſame purpoſe. In the preſent caſe m is given, and hence all the formulæ are eaſily determined. In like manner, on other occaſions, the cauſes are found ſo connected, that one phænomenon being given, many others are immediately ſuggeſted.

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(z) 100 grains contain 20 of zinc, 22 of acid, and 58 of water. B.

## § XII. *Analyſis is to be confirmed by Syntheſis.*

When, by the experiments above propoſed and deſcribed, the ſeveral heterogeneous matters are determined, as to quantity and quality, and reduced by accurate analyſis to perfect certainty, nothing remains but to unite with pure water all the ſeparated maters in due proportion: if then the water, thus treated, exactly and perfectly reſembles the water which has been examined, it muſt afford an irrefragable argument that the analyſis has been properly conducted.

It is indeed but rarely neceſſary to examine all waters with the extreme accuracy above deſcribed; but as the queſtion was concerning the art of examining waters in general, no circumſtance which has any relation to the ſubject could properly be omitted, as all ſuch may, in certain caſes, be uſeful, nay altogether neceſſary.

## § XIII. *The Selection and Correction of Waters.*

Waters, with reſpect to their uſe, may be divided into four claſſes: 1ſt, Thoſe which may without difficulty be applied to daily uſe, ſuch are, good fountain, river, and lake waters. 2d, Thoſe which may indeed be uſed, but yet are attended with certain inconveniencies, unleſs previouſly purified by ſome means or other: to this claſs belong hard waters as they are called, and ſtagnant waters, which have not ſufficient motion. 3d, Thoſe which, on account of their contents, cannot be daily employed for the purpoſes of life, but are uſed at certain times, and under certain regulations, againſt infirmities and diſeaſes; ſuch are the medicated waters. Finally, 4th, Thoſe which, on account of the nature and quantity of their heterogeneous matters, are ſeldom or never uſed internally but nevertheleſs may in other reſpects be extremely uſeful.

(A) It is unneceſſary to beſtow much labour upon the firſt claſs, as daily experience evinces it to be harmleſs, and therefore not to require any correction. In proportion as water is rendered leſs turbid by acid of ſugar, fixed alkali, or ſolution of ſilver, it is the more pure, and with the greater juſtice referred to the firſt claſs

(B) The ſecond claſs is rendered very turbid, by ſolution of ſugar, or of fixed alkaline ſalt, and is conſidered as the more impure in proportion to the quantity of precipitate.—Theſe waters are auſtere, with a ſtyptic diſagreeable earthy taſte; they are apt to occaſion obſtructions; and a long continued uſe of them appears to be unſafe.

Theſe are much leſs fit for obtaining extracts from ſolid ſubſtances than the former claſs, and are therefore much leſs efficacious in brewing, in diſtilling, in preparing decoction of coffee, or infuſion of tea, and many others;—for the waſhing of linen, theſe waters are more or leſs unfit, partly becauſe they do not eaſily diſſolve the impurities, partly becauſe they decompoſe the ſoap, and render it unfit for the purpoſe. Hard waters, for the reaſons above mentioned, are totally uſeleſs in the bleaching of linen; they are alſo unfit for boiling peaſe, beans, and other pulſe, as they neither macerate nor make them ſoft—the ſame is obſerved of old and hard fleſh.

For the purpoſes of preparing hemp and flax by putrefaction, theſe waters are the leſs uſeful, as it is certain that they poſſeſs an antiſeptic power; hence ſubſtances immerſed in them preſerve their ſtrength and texture longer than they would do in better water. This circumſtance affords a hint for trying whether theſe waters may not be uſefully employed in long voyages, as they can, upon occaſion, be eaſily made fit for uſe. Tin, in general, grows black with waters of this ſort;

they have been thought, by ſome perſons, to be unfit for the watering of plants; but, as far as can be conjectured, they ſhould be, in this intention, not only harmleſs, but ſingularly uſeful.

Waters endued with theſe properties are called hard; and in ſuch waters their effects are chiefly produced by an abſorbent earth, united with an acid: if the aerial acid be the menſtruum, boiling alone is ſufficient to correct the water. As this ſubtile acid is expelled by heat, the earth which had been ſuſpended by it is no longer ſoluble in the water, and therefore precipitates, and all the minute particles attach themſelves to the inequalities of the ſubſtances they meet with, and adhere firmly; hence it is that tea-kettles are generally in a ſhort time covered with a cruſt of abſorbent earth; and hence too it happens that the ſurface of pulſe is obſtructed, ſo that the water cannot penetrate them. The hardneſs of waters which depends upon this circumſtance is of little conſequence, as it may be corrected ſimply, by boiling and cooling: but, in order to make it agreeable to the palate after the depoſition of the calcareous matter, it muſt be expoſed to the open air, in broad ſhallow veſſels, by which it recovers from the atmoſphere a portion of the aerial acid.

But if the abſorbent earth be ſuſpended by means of any other acid, it is not ſo eaſily ſeparated; and it is then particularly that it occaſions many of the above-mentioned inconveniences. The decompoſition of the ſoap takes place, becauſe the alkali unites more willingly to the mineral acid of the middle earthy ſalt, than to the oil, which therefore is expelled, and being inſoluble by itſelf, is collected at the ſurface of the water in the form of drops or of a floating membrane.

The other effects are occaſioned either by the middle ſalt itſelf, or take place from hence, that during the boiling a part of the menſtruum flies off, upon which the deſerted baſe cloſely attaches itſelf to ſuch bodies as it meets with. This diſſipation readily happens to the nitrous acid, whether united with lime or magneſia, as alſo to the marine acid, when united with magneſia.

This ſpecies of hardneſs cannot be corrected by boiling alone, but may be removed by a fixed alkali, which precipitates the earthy baſe. For this purpoſe, let a ſolution of pot aſhes, or any other alkaline ſalt, be poured into the water, ſo long as it occaſions any turbidneſs: after the precipitate has fallen to the bottom, it muſt be tried whether any turbidneſs is occaſioned by the addition of more alkali; when no more is found to fall, we may eaſily determine what quantity of alkaline ſalt any given water requires, by weighing the alkali, and its ſolution, previous to the experiment. Finally, let the water, thus purified, be decanted off from the ſediment, or, if neceſſary, filtered.

Stagnant waters are liable to corruption in warm weather, and afford lodgement to millions of inſects. This inconvenience is obviated in the ſouthern parts of Europe, by a ſort of ſandy ſtone, called filters. The water to be uſed for the preparation of food, or for drink, is made to paſs through theſe filters; and is thus freed from all ſuch heterogeneous matters as are not united with it in the way of ſolution.

(c) The cold medicated waters, which poſſeſs peculiar power and efficacy, contain a much larger quantity of aerial acid than the common waters; and, in general, their excellence is chiefly derived from the quantity of their ſubtile acid: however, as they are ſeldom or never without a mixture of other ſaline ſubſtances, it is by theſe that their peculiar effects are ſpecifically determined: for, tho' the Seltzer and Pyrmont waters contain a large proportion of the aerial acid, no one eſtimates their efficacy by the quantity of aerial acid, it being rather dependent upon groſſer ſalts; though theſe latter are certainly vivified by this true mineral ſpirit, and from it receive a more active and penetrating power.—The method of determining the quantity of this volatile acid contained in waters has been explained (VIII. A. B).

Cold medicated waters in general may be divided into ſuch as are impregnated with iron, and ſuch as are deſtitute of that metal; and hence ariſes a conſiderable difference with reſpect to their uſe. Beſides, there are many chalybeate waters which contain iron, either totally or partially diſſolved in vitriolic acid: ſuch waters, when only moderately impregnated, may in ſome caſes be ſucceſsfully uſed, but are for the moſt part improper, and ſometimes highly pernicious; therefore, as the number of chalybeate ſprings is very great, it is of much conſequence to be able to diſtinguiſh the good from the bad, the wholeſome from the noxious: it would be extremely advantageous to eſtabliſh certain characteriſtic marks, by means of which, without any artificial apparatus, without any operoſe experiment, and without a knowledge of chymiſtry, we may in any caſe readily diſcover whether a chalybeate water may be ſafely uſed or not.—The following obſervations will be found particularly uſeful for that purpoſe:—

Let about half a kanne of the water to be examined boil vehemently for about a quarter of an hour, in a ſtone veſſel; let it then be removed from the fire, and cooled; this being done, let about $\frac{1}{4}$ of the water be poured out into a glaſs veſſel; and add 2, 4, or at moſt 6 drops of tincture of galls (VII. [illegible]) If, now, no purple or violet tinge is produced—if no blackneſs appears, even after ſtanding for ſome hours, this is a favourable ſign, affording ſufficient proof that the ſpring is of a good quality, and truly acidulous; but if the vitriolic acid be the menſtruum, it depoſits an ochre

chre upon boiling, without loſing its power on aſtringents.

There occurs alſo a third caſe, namely, where the iron is partly diſſolved by aerial acid, partly by vitriolic acid: Suppoſing, then, the quantity of the latter to be ſo ſmall, that when the former is ſeparated by boiling, the water has no ſenſible effect upon tincture of galls; there will in this caſe, it is true, be preſent a vitriol of iron, but in far leſs proportion than that of three grains to a kanne (VII. D), ſo that it is free from any noxious quality; and even this minute portion may, if neceſſary, be eaſily made viſible; for let the water be boiled until only a twentieth part remains, add then a few drops of tincture of galls, and it will inſtantly be tinged.

It is thus that the hot waters, which are remarkable for efficacy, abound either in atmoſpheric acid, as the Caroline waters in Bohemia, or with hepatic vapour, as thoſe of Aix. Waters containing the groſſer ſalts, without any elaſtic vapour, without a vivifying principle, are as it were dead; and, if not entirely inert, are at leaſt heavy, and of ſmall virtue.

In general, the various medicated waters, both hot and cold, contain fixed principles in a proportion ſo ſmall, that they may be rendered fit for domeſtic uſes, only by boiling and cooling, if ſcarcity of other water ſhould render that proceſs neceſſary.

If a water be rendered unfit for uſe by the admixture of a ſmall quantity of metallic ſalt, this may be removed by a fixed alkali in the manner deſcribed (B); but if it be in large quantity, this inconvenience is occaſioned by the correcting it, namely, that another, though a more innoxious ſalt, ſucceeds to the firſt. Thus, when a vitriol is precipitated, there ariſes a vitriolated vegetable alkali, which, though of a weaker taſte, yet occaſions a degree of bitterneſs, greater or leſs, according to its quantity: however, this ſalt does not produce any noxious effects in the human body, but is reputed a gentle purgative; nor does it prevent the water from being converted to a great number of uſes: hence it appears, that a water contaminated, even by a vitriol, may, in caſes of urgent neceſſity, afford an uſeful ſupply, by means of the remedy juſt deſcribed.

(D) Waters which contain a large quantity of any neutral ſalt, ſuch as vitriolated mineral alkali, common ſalt, &c. or any noxious metallic ſalt, ſuch as green, blue, or white vitriol, are unfit both for internal and domeſtic uſes, though the ſubſtances with which ſuch waters are loaded may be advantageouſly collected, and applied to other uſes.

Sea-water has not only the ſtrong taſte of common ſalt, and the bitter one of ſalited magneſia, but occaſions a very ſingular nauſea, which is frequently attended with vomiting. This nauſeous ingredient is not to be found at all, or but very little, in ſea-water taken up at the depth of ſixty fathom, as experiments made upon water taken up at that depth evidently ſhew; the reaſon perhaps is, that the immenſe quantity of fiſh, worms, and other animals, which inhabit in the ocean, dying, are gradually carried up to the ſurface, and there, by the aſſiſtance of the air, are deſtroyed by putrefaction, (at leaſt this is the caſe with ſuch parts of them as are ſoluble in water); and this putrefactive proceſs is much aſſiſted by the ſalt which, at the ſurface, is preſent in preciſely the quantity neceſſary to promote that operation.

To render ſea-water fit for the uſes of mariners is an art long wiſhed for, and of the higheſt moment. That which is taken up at the depth of ſixty fathoms, or more, on account of its extreme ſaltneſs, is indeed unfit for allaying thirſt; but when mixed with an equal quantity of freſh water, may, beyond doubt, be very uſefully applied to the preparation of food, as it thereby ſaves one half of the ſtock of freſh water.

That water which is found at the ſurface can only be rendered fit for drink by diſtillation, as recent experiments have ſhewn. Many different ſorts of apparatus have been contrived for this purpoſe; and even the vapour ariſing from the veſſels in which food is prepared has been employed. The moſt ſuitable apparatus for this purpoſe is ſuch as will at once yield the greateſt poſſible quantity of water, and require the ſmalleſt quantity of fuel: but this is not to the preſent purpoſe; ſuffice it to ſay, that ſea-water diſtilled, and then expoſed to the air, becomes agreeable and wholeſome;—that which firſt comes over ſhould be thrown away, if it contains any thing putrid. Some part of the marine acid will be diſengaged by violent and long continued boiling;—but this inconvenience may be eaſily avoided by adding at the beginning a little pot-aſhes, which decompoſes the ſalited magneſia.

DIS-

# DISSERTATION III.

## ON THE

## WATERS OF UPSAL.

*Tales ſunt aquæ, quales terra per quam fluunt.*
PLIN.

### § 1. *Good Springs are to be met with in great plenty, at Upſal.*

WHOLESOME water, in ſufficient plenty, is one of the greateſt advantages any place can poſſeſs, and the moſt likely to induce people to ſettle in it; becauſe water is among the moſt indiſpenſable neceſſaries, not only for men and animals cooped up in a ſmall ſpace, but likewiſe for a ſingle family, however ſmall it may be; ſo that ſcarcity or the bad quality of water, expoſes them to numberleſs inconveniencies. If any city in Sweden may boaſt of being fortunate in this reſpect, it is certainly Upſal; for, beſides the river which runs through it, there are ſeveral excellent ſprings, and very good wells. As it is important to know the ſubſtances contained in them, I will relate ſome experiments made with this view; but, to avoid too tedious a detail, I ſhall only ſpeak of the moſt remarkable, ſuch as are common to the whole city, overlooking the others, of which each ſerves only a ſingle family. —I ſhall then confine myſelf to the examination of the ſix following.

1. The ſpring belonging to the citadel riſes at the bottom of the hill on which that fortreſs is built; this eminence conſiſts of ſand; its elevation is of 100 Swediſh feet above the level of the river; it extends on each ſide to a great diſtance from the city; it has various heights and windings, being ſometimes low, and as it were creeping, at others, riſing to a conſiderable height. This hill ſupplies all the water, not only of the ſpring in the citadel, but of the other ſprings and wells to the ſouth of the river, except that mentioned in the 6th ſection. Freſh ones may eaſily be found, by ſinking at its foot.

This ſpring was almoſt forſaken till within theſe few years; and as it was expoſed, it became gradually full of impurities, which obſtructed its veins; ſo that, in February 1767, it was almoſt dry—much leſs rain than uſual had fallen the preceding autumn. It however again made its appearance; but the ſtrongeſt branches opened an-

other

other iſſue nearer the river, where a ſtone baſon was made for it, with the addition of a roof, and where it furniſhes water of a quality ſuperior to all the other ſprings.

2. The ſpring that riſes near the mill of the Univerſity was defended by walls during the whole of the 17th century; but they were deſtroyed in 1702, at the time of the fire, which conſumed great part of the city. As it was neglected afterwards, it was obliged to bear its waters to another place, where it was again ſurrounded by ſtone-work in 1759. As it is very near the banks of the river, it is every ſpring and autumn overflowed by the floods during ſome days.—I ſhall call it the mill-ſpring, though it is ſometimes called St Eric's fountain.

3. The Sandvik ſpring, which takes its name from a little hamlet in the neighbourhood, is ſituated at the diſtance of about ¼ of a mile from the city;—it riſes near the river.

In 1776 the King built a ſtill-houſe for the diſtillation of corn ſpirit, for which it furniſhes a very good water in ſufficient plenty: it is ſo dammed up, as to form a kind of lake.

4. The well which has obtained the name of Odin, and which yet is not of ſo high antiquity, is ſituated near the college of Guſtavus; it is deep, and encloſed with ſtones, but there is no bed to convey away the water, and it is therefore neceſſary to pump it.

5. The well, which bears the name of Luth, formerly profeſſor of divinity, is ſituated further to the north; it is encloſed with ſtone; and they who chuſe to uſe it, are obliged to raiſe it.

6. The draw-well (*puteus tractorius*) ſo named, for I know not what reaſon, is the only one on the other ſide of the river; it is open to every body, nevertheleſs is ſeldom uſed, unleſs for ſome mean purpoſe.

## § II. *A Compariſon of the Phyſical Qualities of the Upſal Waters.*

(A) The water of the ſprings is as limpid as cryſtal; the wells are little inferior, except the 6th, which has a ſlight opal tinge, but leſs perceptible than the river water.

(B) Good water ſhould be taſteleſs: the ſpring in the citadel excels in this reſpect; next follow thoſe of Sandvik, and the mill; but theſe waters, though excellent, impreſs, upon a delicate and practiſed palate, ſomewhat of an earthy ſavour. The water of Odin's and Luth's wells is agreeable, but rather leſs briſk; becauſe it is almoſt ſtagnant. The water of the draw-well, being more impregnated with earth, is by no means agreeable to the taſte.

(C) The temperature of the ſprings is at 6 during almoſt the whole year; in the dog-days, it ſcarce increaſes 2° or 3°: that of the wells is generally at 7. The water of the river follows the changes of the atmoſphere.

(D) There is a ſmall difference in the ſpecific gravity—the river water is the lighteſt of all; next, that of the ſpring in the citadel. Their weight is as follows, at a temperature of 15° (a):

| | |
|---|---|
| Diſtilled water, | 10,000 |
| Pure ſnow water, | 10,000$\frac{1}{4}$ |
| Water of the river, | 10,001$\frac{1}{3}$ |
| of the ſpring in the citadel, | 10,002 |
| of the mill ſpring, | 10,002 |
| of the Sandvik ſpring, | 10,002 |
| of Odin's well, | 10,003 |
| of Luth's well, | 10,003 |
| of the draw-well, | 10,012 |

(E) The water of the ſprings and wells is rather more copious in very wet ſeaſons; but does not diminiſh in long droughts. The mill-ſpring affords 3,900 kannes every hour, or $3\frac{9}{10}$ cubic feet; that of the citadel leſs; but the Sandvik ſpring much more.

## § III. *The Principles of theſe Waters, collected by Evaporation.*

(A) All theſe waters depoſit, during ebullition, a grey powder, which in time forms a cruſt on the internal ſurface of the veſſels. As moſt of them afford only a ſmall depoſition, it is not neceſſary to collect it, as it ſeparates: it is better to continue the evaporation to dryneſs. Having evaporated, at the beginning of June, after a long continuance of dry weather, 6 kannes of each of theſe waters, I found the quantity of reſiduum to be per kanne as follows:

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(a) 6 = 42 or 43, 7 = 44 or 45, and 15 = 59 of F. B.

| | grains. |
|---|---|
| The river water, - - | 8 |
| That of the mill-ſpring, - - | $9\frac{1}{2}$ |
| of the citadel, - - | 10 |
| of the Sandvik ſpring, - | 10 |
| of Odin's well, - - | 12 |
| of Luth's well, - - | $12\frac{1}{2}$ |
| of the draw-well, - - | 51 |

(B) In order to ſeparate the ſaline from the earthy part, the ſeveral reſidua ſhould be waſhed in diſtilled water, dried, and weighed; then ſome marine acid ſhould be poured on the earthy matter, which, in the preſent inſtance, produces a violent effervеſcence, and diſſolves the greater part; what is not diſſolved by the acids cannot be fuſed by itſelf upon coals excited by the blow-pipe, when it has been well waſhed; it reſiſts fuſion after the addition of microcoſmic ſalt; borax produces this effect, but very ſlowly; mineral alkali, fuſed in a ſilver ſpoon or ladle, attacks it with effervesſcence, and completely diſſolves it; the reſidua of the river water, and that of the draw-well, muſt be excepted; for a ſmall portion of them remains inſoluble (*b*): this, therefore, is ſiliceous earth, which although it is ſpecifically heavier than water, ſeems to have been ſuſpended by means of its tenuity; for it is poſſible that, by being pulverized, an heavier ſubſtance may be made to acquire ſo much ſurface, that the friction of the water, which muſt be overcome before it can ſubſide, may form an equilibrium to the exceſs of its weight. Though quartz is of a truly ſaline nature (*c*), yet I can ſcarce believe that it is diſſolved in ſo large quantity; I muſt not, however, omit to remark, that it cannot be ſeparated from our waters, either by filtration or reſt; it is found among the aerated calcareous earth, adhering to tea-kettles.

The ſolution in the marine acid affords only calcareous earth on addition of alkali; wherefore our waters contain only aerated calcareous earth, and a little quartz; but in different quantities, as we ſhall ſoon ſee. The river water, and that of the draw-well, are beſides charged with a little

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(*b*) In the ſecond volume of this Collection will be found an Eſſay on the Blow-pipe, and the way to uſe it.

(*c*) Here the author refers to the 12th Diſſertation of the firſt volume; but there are only 11. It is the 2d of vol. ii.

dry, which we ſaid that the alkali was incapable of diſſolving by means of heat.

(c) The diſtilled water which has been poured on the reſiduum to diſſolve the ſaline part, furniſhes, by ſpontaneous evaporation, common ſalt, ſalited lime, and vitriolated foſſil alkali: the calcareous ſea-ſalt may be ſeparated by highly rectified ſpirit of wine (*d*). The laſt ley, when concentrated by evaporation, affords very often a little mineral alkali, which is of a dark red; but the phlogiſticated alkali does not give a blue precipitate; the water of the draw-well affords moreover a few ſmall priſms of nitre, which may be known by their detonation on charcoal; and, inſtead of Glauber's ſalt, a little ſelenite.

(D) In order to learn the nature of the elaſtic fluid contained in theſe waters, I boiled a certain quantity of each in a glaſs retort, of which the end of the neck was bent upwards, and introduced under a little phial inverted, and full of mercury. The fluid thus obtained is partly abſorbed by water, and conſequently muſt be aerial acid; the remainder is pure air, fit for the ſupport of ignition and reſpiration. It is obvious, that the quantity of common air remaining in the upper part, and the neck of the retort, before the vapours begin to riſe, ſhould be deducted.

(E) Nearly the ſame ſubſtances are to be

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(*d*) See the foregoing Diſſertation, § x. A. § xi. A.

found in all theſe waters; but the quantities differ.—The following are what they contain per kanne:—

| | grains. |
|---|---|
| The river-water contains of aerated calcareous earth, - - | 2 |
| That of the citadel-ſpring, - | 5 |
| of the mill-ſpring, - - | 5½ |
| of Sandvik ſpring, - | 5½ |
| of Odin's well, - - | 5½ |
| of Luth's well - - | 6 |
| of the draw-well, - - | 21 |
| The river-water contains of ſiliceous powder, | ½ |
| of the citadel ſpring, - - | ½ |
| of the mill-ſpring, - - | ½ |
| of Sandvik ſpring, - | ½ |
| of Odin's well, - - | ½ |
| of Luth's well, - - | ½ |
| of the draw-well, - - | 1 |
| The river-water contains of clay, - | ½ |
| The draw-well, - - | 1 |
| The others, - - | 0 |
| The river-water contains of common ſalt, | 1½ |
| The citadel-ſpring, - | 3½ |
| The mill ſpring, - - | 2½ |
| Sandvik ſpring, - - | 2¼ |
| Odin's well, - - | 3¾ |
| Luth's well, - - | 3¼ |
| The draw-well, - - | 18½ |
| The river-water contains of ſalited lime, | 1¼ |

The

| | grains. |
|---|---|
| The citadel-ſpring, | $\frac{3}{8}$ |
| The mill-ſpring, | $\frac{3}{11}$ |
| The Sandvik ſpring, | $\frac{1}{3}$ |
| Odin's well, | $\frac{1}{2}$ |
| Luth's well, | $\frac{1}{3}$ |
| The draw-well, | 1 |
| The river-water contains of vitriolated tartar, | 0 |
| The citadel-ſpring, | $\frac{1}{4}$ |
| The mill-ſpring, | $\frac{1}{4}$ |
| Sandvik ſpring, | $\frac{1}{4}$ |
| Odin's well, | $\frac{1}{3}$ |
| Luth's well, | $\frac{1}{2}$ |
| The draw-well, | 0 |
| The water of the draw-well contains of ſelenite | $8\frac{1}{4}$ |
| The reſt, | 0 |
| The river-water contains of aerated foſſil alkali, | 0 |
| The citadel-ſpring, | $\frac{1}{4}$ |
| The mill-ſpring, | $\frac{1}{4}$ |
| Sandvik ſpring, | $\frac{1}{4}$ |
| Odin's well, | $1\frac{1}{2}$ |
| Luth's well, | $1\frac{1}{2}$ |
| The draw-well, | 0 |
| The river-water contains of extractive mucilage, | $\frac{1}{4}$ |
| The draw-well, | $\frac{1}{8}$ |
| The others nearly, | 0 |
| The water of the draw-well contains of nitre | $\frac{6}{7}$ |
| The others | 0 |

All theſe waters contain about the ſame quantity of air, viz. 6 cubic inches; of which nearly 4 are aerial acid, the reſt pure air, which is carefully to be diſtinguiſhed from common air (*e*)

The quantities juſt laid down vary a little: they increaſe or diminiſh in the different ſeaſons, according to the quantity of rain and ſnow, and from other circumſtances. It is poſſible, nay, it does undoubtedly come to paſs, that the proportions undergo ſome change in the courſe of ſeveral years; for at firſt the water diſſolves with facility all the ſoluble ſubſtances of the ſtrata over which it paſſes; and after it has ſucceſſively carried them away, it meets with no more, at leaſt the quantity is diminiſhed: beſides, theſe ſubterraneous canals themſelves are liable to various changes. In one place the old ones are ſtopped up, in another, new ones are opened: now, ſince the particles of the ſtrata traverſed by the waters are not conſtantly of the ſame nature, it cannot appear ſtrange that they ſhould partake of theſe varieties.

(F) We have already obſerved, that the ſiliceous earth was ſuſpended in our waters, on account of the extent of ſurface ariſing from the tenuity of its particles: the ſame remark may be applied to the greater part of the aerated calcareous earth, which ſeparates along with the ſilex during ebullition.

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(*e*) See above, Diſſ. I. § XXII.

ebullition. In reality the water, when rarefied by the heat, loſes ſo much of its ſpecific gravity that the earths are precipitated: the increaſed mobility of the particles of the water facilitates this ſeparation. The calcareous earth held in ſolution by the aerial acid ſtill further contributes to the production of this effect; becauſe, as the heat volatilizes the ſolvent, it joins the ſubſtances which are only diffuſed, and enlarges their molecules. It is now eaſy to conceive why tea-kettles come to be covered with a calcareous cruſt, of which the quintal contains about 3 or 4 pounds of particles of quartz.

A kanne of water, completely aerated, is capable of diſſolving 27 grains of aerated calcareous earth (f); wherefore our waters, which contain in that quantity only four cubic inches of this acid, will diſſolve little more than a grain. It will perhaps appear ſtrange that the particles which are ſuſpended in a fluid, only on account of their ſmallneſs, ſhould not impair its tranſparency: but, in the firſt place, I have remarked, that the water of the draw-well, which contains moſt earth, is a little opal coloured; on the other hand, it ſhould be conſidered, that particles of ſufficient tenuity to paſs through the filter, and to remain ſuſpended in water by friction alone, muſt neceſſarily be tranſparent, at leaſt as long as they are ſurrounded by water.

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(f) See Diſſ. I. § IV.

## § IV. *Effects produced by Precipitants on the Waters of Upſal.*

(A) Theſe waters ſcarce heighten paper coloured blue by turnſole; they give a ſlight ſhade of blue to paper made red by Brazil-wood; they do not at all alter paper tinged by turmeric. The cauſes of theſe changes have been aſſigned above (*g*).

(B) Spirituous tincture of galls ſhews no veſtige of iron, any more than the phlogiſticated alkali.

(C) The mineral acids produce no perceptible change. If a little of the cryſtallized acid of ſugar be thrown into them, it generally forms white ſtreaks as it paſſes through the liquor, and a white powder, which is real ſaccharated calcareous earth, collects round it at the bottom of the veſſel. Theſe phænomena are but faintly exhibited by the river water; they are more perceptible in that of the ſprings; and very evident in thoſe of the wells, eſpecially of the draw well. The ſaccharine acid alſo occaſions a ſmall precipitate in ſnow-water, but it is not viſible for ſome hours (*h*). This acid ſcarce makes our waters turbid after boiling, eſpecially the ſpring-waters, which depoſit moſt of their earth during the boiling.

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(*g*) See Diſſ. II. § VII.

(*h*) See below, Diſſ. VIII. § VI.

(D) The fixed alkalis precipitate a white earth, which on examination is found to be real calcareous earth.. A copious precipitation takes place immediately in the draw-well water; in the reſt it is ſlower, and far leſs conſiderable. The water of the draw-well is ſcarce made turbid, after boiling, by addition of alkali.

(E) Lime-water turns white inſtantly, and a calcareous precipitate is formed; this is owing to the aerial acid which combines with the pure calcareous earth, and carries down with it the earth which was held in ſolution by the exceſs of this acid, and which is then deprived of its ſolvent (*i*).

If theſe waters be made to boil briſkly, and a larger quantity of lime-water be then added, a ſlight turbid appearance is perceived, which announces the obſtinate adherence of the laſt portions of aerial acid.

(F) Salited ponderous earth in the ſpace of 24 hours cauſes no alteration in the water of the river; a very ſlight one in that of the ſprings; and a much more perceptible one in that of the wells, particularly of the draw-well, from which it precipitates a white powder; this clearly announces the preſence of the vitriolic acid (*k*).

(G) Salited lime produces no change in theſe waters;

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(*i*) See Diſſ. I. § XI.

(*k*) See Diſſertation II. § VII. and the Eſſay already quoted on the Elective Attractions.

waters; they indeed contain no ſubſtance capable of decompoſing it.

(H) If a piece of alum be thrown into any of theſe waters, it is decompoſed as it diſſolves: the aerated calcareous earth attracts the vitriolic acid; and the argillaceous baſis, left alone, forms, as uſual, a ſtratum parallel to the bottom of the veſſel.

(I) The ſolution of ſilver clouds all theſe waters;—it ſcarce affects ſnow-water.

(K) Nitrated mercury, made without heat, occaſions a white precipitate in them; that made with the aid of heat occaſions a yellow precipitate, which, in the water of the draw-well, is very copious. Snow-water is ſcarce rendered turbid by the former of theſe preparations, and very ſenſibly by the latter.

(L) Corroſive ſublimate ſometimes occaſions a ſlight precipitate, of a white colour, which ſhould perhaps be attributed to a little volatile alkali.

(M) Acetated lead inſtantly renders theſe waters milky. The lead precipitated in the river-water is entirely ſoluble in diſtilled vinegar; a ſmall part of that precipitated in the water of the ſprings remains inſoluble in that menſtruum; but it is viſible only when large quantities have been ſubmitted to examination. More of the precipitate formed in the water of the wells reſiſts the action of vinegar, which attacks ſalited but not vitriolated lead.

(N) A piece of martial vitriol, thrown into theſe waters, occaſions a precipitation of martial earth as it diſſolves. If a few drops of the ſolution of this vitriol be poured into a ſmall phial, containing about an ounce of water, and the precipitation be immediately made by a few drops of liquid vegetable alkali, the precipitate, which at firſt is green, ſoon changes to a yellow colour, though the bottle is full, and well ſtopped: this phænomenon indicates the preſence of pure air in our waters, which attracts the phlogiſton of the precipitate. Let the ſame operation be repeated on theſe waters immediately after boiling; if they are kept in well cloſed phials, the martial precipitate will preſerve for whole years the green colour which it owes to the phlogiſton.

(O) Soft Venice ſoap, rubbed in our waters, produces a copious foam, except in that of the draw-well, in which it lathers very imperfectly: they all take up a portion of the ſoap, which renders them milky;—even that of the draw-well does not recover of itſelf its former tranſparency.

## § V. *On the Uſes for which theſe Waters are fit.*

From theſe obſervations we are enabled to judge of the ſuperior excellence of the Upſal waters: that of the draw-well muſt be excepted; but it may be corrected by boiling, and would be much improved, if it was oftener drawn, and leſs ſtagnant; it is indeed not quite crude, ſince it diſſolves a little ſoap. If we overlook this water, and that of the river, they are all agreeable to the taſte, when they are drank cold; but the ſpring belonging to the citadel has ſome advantage over the others: the waters of all the ſprings, however, are equally good to be drank hot. The river-water is generally uſed for waſhing, for boiling garden-ſtuff, making coffee, beer, and ſpirit of corn, principally becauſe a large quantity may be procured with leſs trouble. The water of all the ſprings, and the two firſt wells, would ſerve equally well, and indeed, on ſome occaſions, would be preferable; for inſtance, for the waſhing of fine linen, for ſtarching it, and tinging it with a ſlight blue, by means of turnſole—the water of the ſprings ſhould be preferred, becauſe that of the river gives it a reddiſh hue.

# DISSERTATION IV.

## ON THE ACIDULOUS SPRING IN THE PARISH OF DENMARK.

Juſtâ confeſſione omnes terræ quoque vires aquarum ſunt beneficii. Quapropter ante omnia ipſarum potentiæ exempla ponemus. Cunctas enim quis mortalium enumerare queat? Plin.

### § I. *Of medicinal Waters in general.*

PHyſicians have two principal ways of curing, or at leaſt of alleviating, the numberleſs maladies by which the human frame is aſſailed. They either employ remedies of ſuch efficacy as to produce an evident effect in the courſe of a few hours; or elſe they preſcribe a frequent repetition of mild medicines in ſmall doſes, of which the action does not become ſenſible till ſeveral weeks, and ſometimes till ſeveral months, have elapſed: among the latter, mineral waters are juſtly enumerated; they effect ſurpriſing cures every day, and ſuch as could not be expected from any other mode of cure hitherto diſcovered. We are not to attribute theſe effects to ſimple water, conſidered by itſelf; for, according to ſuch a ſuppoſition, they would be produced in every place alike, but to the ſubſtances mixed with it, and diſſolved in it, by which it is ſharpened, and, as it were, armed with ſuch efficacy. Hence, in all ages, good phyſicians, deſirous of eſtabliſhing the ſalutary art on a firm foundation, have conſidered it as a duty incumbent upon them to ſubmit to chymical analyſis ſuch waters as were famous for the cure of any diſeaſe; and if this taſk had been performed with proper exactneſs, we ſhould now be enabled to form a certain judgement upon the uſe and virtues of all mineral waters. When the compoſition of any medicine is perfectly underſtood, and its mode of operation has been carefully obſerved on various occaſions, the phyſician has then fixed and clear notions concerning its effects, which cannot fail of becoming highly ſerviceable in future, whenever a mixture of the ſame ſubſtances, in the ſame proportion, is diſcovered: if ſo neceſſary a part of knowledge has not been hitherto acquired, it is becauſe the analyſis of waters forms one of the moſt difficult problems in chymiſtry. The ſubſtances held in ſolution are of various kinds, and always in very ſmall quantity: not to mention that ſeveral of theſe ſubſtances, and thoſe the moſt important, have not been well known till of late; and hence it happened, perienced, that the moſt accurate analyſes have fallen very far ſhort of perfection.

Henceforward, let us rely on no analyſis, until a mineral water, in every reſpect reſembling the natural water, has been recompoſed, with pure water and the ſubſtances that have been obtained.

## § 11. *Situation of the Spring at Denmark.*

The ſpring which I propoſe to examine with ſome attention is ſituated at the diſtance of about three-quarters of a mile ſouth-weſt from Upſal, in the pariſh of Denmark. In the neighbourhood ſeveral veins of mineral water have been diſcovered, but four eſpecially are in repute; they are very near together, and riſe in the meadow Wallby, of which the ſoil is argillaceous. Theſe acidulous ſprings were diſcovered in 1733, and frequented with great advantage; they were afterwards forſaken and neglected, for what reaſon I know not, till the ſpring of the preſent year (*a*). Then Ab. Scoderberg, a ſkilful ſurgeon of the

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(*a*) The celebrated G. J. Wallerius publiſhed, thirty-ſix years ago, a deſcription of this fountain newly diſcovered, in a work entitled, "Tankar om Danemarks Halſo-"bruae." He mentions ſome fortunate cures effected by them; but they have probably undergone great changes ſince that time, as will appear from a compariſon of his deſcription with that which I ſhall give below.

Upland regiment, cauſed a proper reſervoir, and the neceſſary buildings, to be conſtructed, a little nearer the royal road than they were before. Laſt ſummer a great concourſe of people reſorted to theſe waters, and took them with benefit. This fountain lies in a plain between the ſouth and the weſt: there is an eminence ſituated at ſome diſtance, from which the ſprings probably derive their origin.

## § III. *Phyſical Qualities of this Fountain.*

The four veins afford much more than one hundred kannes of water every hour, which appears very limpid; but, when compared with that of the ſprings at the mill, or citadel, a conſiderable difference is perceived. When it is at reſt, or runs but ſlowly, its ſurface ſhews the ſeveral colours of the rainbow, and a depoſition of ochre is ſeen at the bottom. If the reſervoir has been kept long cloſed, a ſtrong hepatic ſmell is exhaled from it, which may alſo be perceived after ſhaking the water for a few moments in a corked bottle, and then applying it to the noſe.

This water has a taſte of ink, but it is very ſoon found to be in a great meaſure deſtitute of that briſk and agreeable acid which makes the acidulous ſprings in repute ſo volatile and ſo efficacious.

The temperature is between (*b*) 9° and 10°.

The ſpecific gravity is to that of diſtilled water as 100,26, 10,000.

## § IV. *The Quantity of Aerial Acid.*

I have made many experiments to determine how much of that elaſtic which is properly called the aerial or atmoſpherical acid, is contained in this acidulous ſpring. One part changes ten parts of the blue tincture of turnſole to a very perceptible red; however, four parts do not alter this tincture ſo much as one part of the Spa water.

Agitation in a corked phial produces rather more bubbles in this water than in that of common ſprings treated in the ſame manner. If what has been ſaid above of its taſte be recollected, it will appear that there is a deficiency of aerial acid; as will be ſeen ſtill more clearly, if it be diſengaged by heat, and collected by means of quickſilver (*c*): in truth, it is ſcarce found to contain ſeven cubic inches in a kanne; whereas the ſame quantity of Spa and Pyrmont waters, as they are imported into Sweden, contain, the former near ſeven times, and the latter thirteen times as much.

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(*b*) 48 and 50. B.

(*c*) See Diſſ. II. § VIII.

## § V. *The Principles obtained by evaporation.*

In order to obtain the fixed ſubſtances which do not fly off at a boiling heat, I evaporated given quantities of this water in the following manner: —after expoſing it to the fire for four minutes, I ſuffered it to cool. I then filtered it, and obtained a kind of ochre, amounting to 1¾ grain per kanne. As it is neceſſary to adopt ſome proceſs for procuring an equal exſiccation of the reſidua before they are weighed, I expoſe them for fifteen minutes to an heat of 100° (*d*). This term, which is that of boiling water, ſeemed the moſt convenient, becauſe it may always be very eaſily obtained.

The filters ſhould be dried at this degree, and afterwards weighed, in order to eſtimate what they contain. It is indeed impoſſible to prevent ſome very ſubtile particles from paſſing through; but it is ſtill more difficult to ſeparate the ſubſtances completely which adhere to and penetrate white paper not alumed, which is proper for this purpoſe. After thus weighing the ſubſtance, along with the filter, we have only to deduct the weight of the latter to find exactly that of the former: moreover, this mode of drying is more convenient, becauſe, after the filter and its con-

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(*d*) 212° of Fahrenheit. B.

tents have been left expoſed to the air, it may be rolled up, and put into a glaſs phial, and the boiling heat thus applied to it.

My aim, by this firſt evaporation, was to learn, whether a little calcareous earth or magneſia was not held in ſolution by the aerial acid; for we have ſeen that they loſe, at this temperature, the exceſs of that fluid neceſſary for their ſolution, when they precipitate, and remain on the filter, along with the ochre. In the preſent inſtance, there was no obſervable veſtige of them, and the reſiduum did not effervеſce in the leaſt with the acids. I then continued the evaporation till the water was reduced to $\frac{1}{10}$; and after having filtered the liquor again, the reſiduum, when dried, amounted to $2\frac{3}{4}$ grains per kanne.—All the following numbers are to be referred to this meaſure, which I will mention no more, and which ought always to be underſtood, unleſs another is particularly ſpecified.—When the evaporation of the reſt was finiſhed, and it had been dried, there remained 16 grains; wherefore we have $20\frac{1}{2}$ grains for the ſum of the ſeveral reſidua, of which we are now to examine the nature.

## § VI. *This Water contains aerated vitriolated Iron.*

The preſence of iron is known by the ochre which it depoſits, its taſte, the black colour it ſtrikes with aſtringents, and the blue colour produced by phlogiſticated alkali. But it ſoon appears, that a very ſmall portion only of this metal is held in ſolution by the volatile acid; that the greater part is combined with an heavier and a more fixed acid, becauſe this water retains the property of turning black with aſtringents (*e*), after having been long expoſed to the open air, and even after boiling, to the laſt drop; whence we may conclude, that it is a vitriolic water; for if the iron was diſſolved by the aerial acid only, it would be all precipitated by boiling: on the contrary, water impregnated with martial vitriol, kept in an open veſſel, is continually depoſiting ſucceſſive portions of ochre; becauſe, as the metallic baſis gives out its phlogiſton to the air, which attracts it with great eagerneſs, the acid can no longer hold the ſame quantity as before in ſolution; for, as iron is more deprived of inflammable principle, it requires more acid for its diſſolution, and heat promotes the diſſipation of the phlogiſton. In water containing a very ſmall

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(*e*) It ſhould be obſerved, that an exceſs of tincture of galls may eaſily miſlead, becauſe common water, containing a little aerated calcareous earth, without an atom of iron, precipitates it. The precipitate is of a yellowiſh white colour, and not perceptible at firſt; if a little iron ſhould be preſent, there will be a mixture of violet-coloured particles, and in two hours a greeniſh tinge will appear.

portion of vitriol of iron, it may be ſo far diminiſhed by this means, that neither tincture of galls nor phlogiſticated alkali produce any ſenſible effect.

According to ſome modern chymiſts, whatever water gives a blue colour with phlogiſticated alkali certainly contains green vitriol; but this opinion is refuted by experiment, for diſtilled water, impregnated with aerated iron, aſſumes the ſame tinge, only a little more ſlowly; a circumſtance that will not ſurpriſe thoſe who conſider the unequal ſtrength of the two acids with which the iron is combined: it is even certain, that vitriol of iron, completely ſaturated, does not afford a fine Pruſſian blue ſo ſpeedily, nor ſo copiouſly, as that in which there is exceſs of acid; for the precipitate of the latter ſhews inſtantly the fineſt blue, whilſt that of the former has at firſt a blackiſh or whitiſh tinge. In the preſent inſtance, the vitriolic acid is more clearly detected by other proceſſes: —the addition of vinegar of lead produces ſmall angular grains, which are not attacked by vinegar; beſides, if the iron is precipitated by the fixed vegetable alkali, a true vitriolated tartar may be obtained by cryſtallization. Now, this could never happen, if no vitriolic acid was preſent to combine either with the lead or the alkali.

It is poſſible to determine the quantity of iron, by the colour which the water receives from the tincture of galls; by trying, with an equal number of drops of the tincture, equal quantities of water, more or leſs impregnated with vitriol: when the ſhade is the ſame, the bulk of water equal, and the quantity of the aſtringent principle the ſame, the quantities of iron muſt needs be equal; and as the operator knows how much is contained in the ſolution which he made, he will alſo know the weight of that contained in the water which he is analyſing: this proceſs is not to be rejected with diſdain; but to be certain of the reſult, requires a tedious exactneſs. Others, after waſhing the whole reſiduum in pure water, then drying and weighing it, pour one of the mineral acids upon it; and afterwards, pouring off the acid, waſh what remains undiſſolved; then dry and weigh it again, and from the diminution of weight collect that of the iron. This method is not a bad one; but care muſt be taken not to uſe too ſtrong an acid, not to add too much of it, and not to continue the digeſtion long; for if there ſhould be any ſelenite in the reſiduum, as it is ſoluble in the acids, they may take up more or leſs of it, perhaps the whole, and the operation would not be exact;—the ſureſt way is to precipitate all the iron with phlogiſticated alkali.

A kanne of this water furniſhes, by this proceſs, near 16 grains of precipitate, which contain about 14 grains of martial vitriol, as 100 of this ſalt in cryſtals afford 115 of Pruſſian blue: the ſmall quantity of iron diſſolved by the aerial acid muſt be deducted; but this ſcarce exceeds $\frac{1}{4}$ of a grain; for 100 cubic inches of this acid take up only 4 of iron (*f*).

## § VII. *Of the Selenite.*

When the iron has been parted from the reſiduum by means of an acid, a whitiſh matter, of the weight of 14 grains, remains, which exhibits almoſt all the properties of ſelenite; it is alſo found in the ochre collected by the firſt filtering (§ v.). All the reſiduums, and eſpecially the laſt, are eaſily fuſed, with an appearance like boiling, upon coals excited by the blow-pipe; they leave a globular matter, which is attracted by the magnet, unleſs it has been too long expoſed to the fire. The little ſolubility of this ſubſtance in water, and the appearances it ſhews in the fire, whether by itſelf or in mixture, ſufficiently ſhew it to be ſelenite. Above all, it may be known by decompoſing it by fixed alkali in the liquid way; for the calcareous earth is precipitated, and by cryſtallization Glauber's ſalt or vitriolated tartar may be obtained, according to the kind of alkali employed.

The ſelenite may be ſtill better ſeparated from the iron, by boiling the dried reſiduum in 500 times its weight of diſtilled water, which diſſolves

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(*f*) See Diſſertation I. § XIV.

all the ſaline part, and afterwards it is eaſy to determine the quantity by weighing, after it has been dried, the ochre which remains.

### § VIII. *Of the Siliceous Powder.*

If the ſelenite is diſſolved along with the iron, (§ VI. VII.), there remains about half a grain of very fine powder, which reſiſts the acids, even when aſſiſted by heat;—when it has been waſhed and examined, it is found to be true ſiliceous earth.

### § IX. *Of the Salts.*

By a ſlow evaporation of the water with which the reſiduum has been waſhed, about three grains of perfect cryſtals of Glauber's ſalt may be obtained, which contain only the ſmall portion of iron that the water of cryſtallization retains: the remaining liquor is greeniſh, and does not eaſily afford cryſtals; but when reduced to dryneſs, it affords two grains of a deliqueſcent matter of an aſtringent, and at the ſame time ſalt taſte: this matter, tried by different teſts, and eſpecially by precipitants, is found to be vitriol, but in a highly dephlogiſticated ſtate, and a little Glauber's ſalt mixed with common ſalt; this laſt ſhews itſelf both by its taſte, and one or two cubical cryſtals, but chiefly by the grey and acrimonious fumes which ariſe, and by the particular ſmell which it exhales, when it is moiſtened with a little concentrated vitriolic acid, and ſome wet ſubſtance is held over it.

## § x. *Principles of the Denmark Water.*

From what has been ſaid before, it may be concluded, that a kanne of the Denmark water contains,

| | | | |
|---|---|---|---|
| of aerial acid | - | 7 | cubic inches |
| of aerated iron | - | 0¼ | grains, § VI. |
| of vitriol of iron | - | 14 | § VI. and IX. |
| of Glauber's ſalt | - | 3½ | § IX. |
| of ſelenite | - | 14 | grains, § VII. |
| of com. ſalt, at moſt | | 0¾ | § IX. |
| of ſiliceous, nearly | | 0¼ | § VIII. |

In all 32¾ grains, which conſiderably exceed the weight of the whole reſiduum (§ v.); but this difference ariſes from the water of cryſtallization, which here enters into the account, and which the heat had diſſipated when the reſiduum was weighed the firſt time. If the ſame ſubſtances, in the ſame proportions, are added to diſtilled water that has loſt its empyreuma, a ſolution perfectly reſembling the natural water in taſte and every other quality will be obtained; and thus our analyſis is completely confirmed by ſyntheſis.

It

It ſhould however be added, that the acidulous water of Denmark contains a little extractive vegetable matter, which without doubt it has received from the roots that it met with in its paſſage under ground; and probably this is what impairs its limpidity (§ 111.). One may ſometimes diſcover, by mere inſpection, fragments of vegetables.

The variegated pellicle on the ſurface does not come from any mineral unctuous ſubſtance, but from iron in a certain degree dephlogiſticated: ſimilar pellicles appear on ſolutions of any metallic ſalts expoſed to the air; they are alſo formed by iron diſſolved in water by the aerial acid. Pure air forcibly attracts the inflammable principle; and it is evident, from many experiments, that the colours of metallic calxes vary according to the quantity of phlogiſton of which they have been deprived. The hepatic ſmell plainly points out the way employed by nature to impregnate this water with its mineral particles.

Such are the ſubſtances contained in the acidulous ſprings at Denmark; to treat of their uſes and efficacy does not fall within my plan. It is however, in general, evident that they muſt poſſeſs virtues different from thoſe of lighter waters in which the iron is diſſolved by the aerial acid: but although the ſame effects which the latter every day produce, cannot be expected from them, they probably poſſeſs greater power and efficacy in thoſe caſes which may require a vitriolic water.

Moreover, the vitriol and ſelenite are here the active principles; the other ſubſtances are preſent in ſuch ſmall quantity that they can have little ſhare in producing the effects. With reſpect to the ſelenite, it is found in the Pyrmont water, as well as many other waters of high reputation; but there is great reaſon to queſtion its ſalubrity.

# DISSERTATION V.

## OF

## SEA-WATER.

### § 1. *Water taken up from the Sea at a conſiderable Depth.*

THE experienced Dr Sparrman, who lately viſited the Southern Ocean in company with the Forſters, and who in that voyage, with indefatigable care, has inveſtigated, collected, and deſcribed the wonderful ſtóres of nature, endeavoured, during nis paſſage from the Cape of Good Hope to Europe, to aſcertain the nature and properties of ſea-water, taken from a very great depth:—for this purpoſe, a number of glaſs bottles, with narrow necks, and well corked, were ſucceſſively ſunk, in the beginning of June 1776, about the latitude of the Canaries; one bottle taken up from the depth of 80 fathom, was found cracked in the body by the preſſure of the ſurrounding fluid; another, ſunk to 30 fathom, had the cork a little thruſt in, but not ſo that any water could enter; it was therefore let down to 60 fathom, and when brought up, was found filled with water up to the third part of its neck—in that place the cork, which had been thruſt in, ſtuck, ſo as not to permit any water to eſcape: afterwards many bottles were filled at that depth, which, upon his return, Dr Sparrman ſent to me, requeſting me to examine with all poſſible accuracy the heterogeneous matters it contained.

## § II. *Its Habits with Precipitants.*

This ſea water had no ſmell, and the taſte intenſely ſalt, not agreeable indeed, but by no means nauſeous, like that which is got at the ſurface.

(A) Paper tinged with Braſil-wood was rendered a little blue, that with turnſole had its colour ſomewhat heightened: theſe phænomena ſhew ſome weak tokens of an alkaline ſubſtance; namely, magneſia diſſolved by means of aerial acid. Tincture of turnſole was not ſenſibly changed.

(B) Acid of ſugar immediately precipitated a white powder conſiſting of ſaccharated lime.

(C) Fixed alkali quickly precipitated a white earth, which on examination proved to be magneſia.

(D) Salited terra ponderoſa immediately threw down a ſpathum ponderoſum.

(E) Phlogiſticated alkali produced no ſigns of a blue colour.

Hence we may diſtinctly perceive the preſence of lime (B), of magneſia (C), of vitriolic acid (D); —with reſpect to common ſalt there was no doubt

In order to determine the quantity and quality of the proximate principles, I continued the inveſtigation in the following manner.

## § III. *Principles collected by Evaporation.*

A kanne of this water (the ſpecific gravity, compared with diſtilled water, was 1,0289) upon evaporation to dryneſs, yielded a reſiduum which, when well exſiccated, weighed 3 ounces 378 grains.

(A) This reſiduum, well waſhed with alcohol, and dried, was diminiſhed in weight 380 grains.

The ſolution, diluted with diſtilled water, depoſited, on the addition of mineral alkali, a magneſia; and the liquor, on evaporation, yielded common ſalt.

(B) In order to diſcover whether there was any vitriolated magneſia preſent, I added to the ſaline maſs, waſhed with alcohol, a ſmall quantity of warm water, and ſuddenly decanted it off. This water, on examination, ſhewed no ſigns of vitriolated magneſia, either in taſte or by precipitation, and contained nothing but a ſmall portion of common ſalt.

Vitriolated magneſia is very eaſily diſſolved in boiling water, whereas of pure common ſalt ſcarcely any more is taken up by hot than by cold water; by the above method, therefore, they may eaſily be ſeparated. Some moderns contend, that more of common ſalt is taken up by cold, than by warm water; but this aſſertion is contrary to the nature of things, and to experience: upon accurate examination, I found the quantities taken up by boiling water, and by water of a moderate heat, to be reſpectively as 77 to 71¼.

(C) The common ſalt was diſſolved in a quantity of cold water ſo ſmall, that it could take up no more; and therefore a white powder remained, which appeared to be gypſum.

(D) This gypſum excited in diſtilled vinegar a very ſlight efferveſcence, which ſoon went off, but the gypſum was ſcarce ſenſibly diminiſhed.

(E) Upon collecting and weighing all the contents, each kanne is found to contain

| | | Ounces. | Grains. |
|---|---|---|---|
| of common ſalt, | - | 2 | 433 |
| of ſalited magneſia, | - | 0 | 380 |
| of gypſum, | - | 0 | 45 |
| | | 3 | 378 |

The magneſia which adhered to the gypſum, and had been diſſolved by the aerial acid, is found in ſuch ſmall quantity as not to amount to $\frac{1}{8}$ of a grain.

## § IV. *The Uſes of Sea-Water.*

If ſea-water taken from a conſiderable depth be always of the ſame nature with that above examined, we may conclude that ſuch water is free from the ordinary nauſeous flavour; and this ſuppoſition alſo agrees with other phænomena; for the innumerable croud of fiſh, inſects, and vegetables, that grow, live, and periſh in the water, as ſoon as they begin to grow putrid, ſwell, and riſe to the ſurface, or at leaſt ſuch parts of them as are extracted by the water: on the ſurface theſe meet with a ſufficient quantity of ſalt, and free acceſs of air, circumſtances which wonderfully promote putrefaction. This deſtruction is a neceſſary part of the œconomy of nature; and thus many circumſtances, with joint force, contribute to this operation; the neceſſary conſequence of which I apprehend is, that nauſeous and loathſome taſte occaſioned by the putrid particles near the ſurface;—but, whatever be the cauſe, provided the fact be uniform and conſtant, an advantage of no trivial nature may be derived from it for the benefit of ſeamen; for ſea-water, taken up at this depth at leaſt, diluted with an equal quantity of freſh water, may be employed for the boiling of proviſions, by which means one half of the freſh water will be preſerved; and perhaps in time of urgent neceſſity a greater ſaving might be made.

# DISSERTATION VI.

## OF THE ARTIFICIAL PREPARATION OF COLD MEDICATED WATERS.

### § 1. *Reaſons for the preſent Undertaking.*

THERE are four remarkable ſpecies of mineral waters; namely, the Seydſchutz, Seltzer, Spa, and Pyrmont waters, which are imported into Sweden; phyſicians having found theſe ſo uſeful againſt infirmities and diſeaſes, that a conſiderable quantity of them is preſcribed and uſed every year.

But as theſe waters either cannot be had amongſt us at all during the winter and ſpring, or at leaſt not freſh, although the moſt powerful remedy for the diſeaſes which prevail at that time of the year: as the poor cannot purchaſe them at the price which they commonly bear;—as they loſe more or leſs of their virtue during the voyage;—and finally, as they draw yearly conſiderable ſums of money out of the kingdom;—I thought it worth while to examine, with all poſſible accuracy, the conſtituent principles of theſe waters: hoping that, theſe principles being once known, the waters themſelves might be prepared in any part of the world. Whether or not I have ſucceeded let the candid and ſkilful judge from the following pages.—We now proceed to the analyſis of theſe waters, as they muſt be thoroughly known, before they can be imitated.

## § II. *Analyſis of Seydſchutz Water.*

### *Principles collected by Evaporation.*

The taſte of Seydſchutz water is extremely bitter and diſagreeable: in boiling it ſeparates a white powder, which, collected on a filter, waſhed and dried, exhibits a genuine aerated lime; for, when ſaturated with vitriolic acid, it is all converted into gypſum.

(B) After the greateſt part of the water is evaporated a gypſeous pellicle appears on the ſurface, which muſt be carefully taken away, as long as the leaſt veſtige of that ſalt ſhall appear during the evaporation. The gypſum, collected and waſhed, efferveſces a little with diſtilled vinegar; this efferveſcence depends upon the admixture of magneſia alba, which may alſo be precipitated from the acid menſtruum by alkali of tartar: however, a ſmall quantity of gypſum will remain in the water, even after it has ceaſed to produce diſtinct pellicles.

(c) The reſiduum is of a brown colour; and on repeated evaporation this water yields, almoſt to the laſt drop, cryſtals of a bitter ſalt, which is totally decompoſed by lime-water, and is therefore genuine (*a*) vitriolated magneſia: for Glauber's ſalt contains the mineral alkali, which does not yield the vitriolic acid to lime. The cryſtals, collected and diſſolved in a ſmall quantity of water, depoſit on the bottom of the veſſel that ſmall portion of gypſum above mentioned (B). Theſe cryſtals alſo contain a ſalited magneſia, which partly unites with the water of the cryſtals, partly adheres to them externally, and may be ſeparated by ſpirit of wine.

Salited lime cannot exiſt in water which contains vitriolated magneſia, for the proximate principles of theſe ſalts are immediately changed by a double elective attraction; the vitriolic acid ſeizing the lime, and leaving the magneſia to the marine acid.

Upon repeating the analyſis of Seydſchutz water, I found that the different ſubſtances may be ſeparated as well, or better, by continuing the

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(*a*) On Magneſia, § v.

evaporation at firſt to dryneſs, and afterwards ſeparating the one from the other.

(D) In order to determine the quantity of fixed air contained in the water, I at firſt made uſe of a copper cylindrical veſſel, fitted with a conical top (A B C D, tab. ii. fig. 1.) into this I put another leſſer cylinder (E F G H) open at the bottom, and ſtanding upon three feet, but cloſed at the top, except the little tube I, whoſe upper orifice ſhould ſtand about half an inch beneath the ſurface of the water, filling the veſſel; and the proceſs is thus conducted:—the external and internal veſſels are filled with the water under examination; then a glaſs bottle, filled with warm water, is inverted, by means of the ſpoon L, in ſuch a manner over the tube I, that no air bubbles ſhall enter: the water is then boiled as long as the vapour, and that only, ariſes in the form of bubbles; mean time the water contained in the internal veſſel is forced by the heat to emit its air, which riſes through the tube I, and is collected in the bottle; if neceſſary the firſt bottle may be removed, and ſet in a veſſel of warm water, while another is inverted over the tube as quickly as poſſible, in order to prevent the eſcape of any of the air: finally, the ſpace occupied by the air in one or more bottles is to be meaſured, and that in an heat of 50°, to prevent the abſorption of air.

This ſpace, compared with the capacity of the internal veſſel, ſhews nearly the quantity of air contained in a given meaſure of the water. Such

a

a method I practiſed at firſt; but, although the water in the bottle be heated to the 50th degree, I have found that it abſorbs ſome of the air; I therefore afterwards made uſe of mercury, which, if the operation be properly conducted, ſhews exactly the quantity of air required (ſee Analyſis of Waters, VIII. A, B). The bulk varies according to the gravity and temperature of the atmoſphere;—hence we ſhould, as much as poſſible, chuſe determined degrees of heat and weight.

It is alſo to be obſerved, that the aerial matter thus collected generally conſiſts of two different elaſtic fluids, the one perfectly agreeing with the aerial acid, the other with pure air; that is, air fit for ſupporting flame and animal reſpiration. Common water abſorbs the firſt of theſe, but not the latter, being already ſaturated with it; and by this method the two fluids may be ſeparated to a certain degree.

(E) The ſeveral matters obtained by the analyſis above deſcribed are in quantity as follows: a Swediſh kanne (that is, 100 cubic inches) of Seydſchutz water contains

| | grains. |
|---|---|
| of aerated lime - - - | 4½ |
| of vitriolated lime - - | 24½ |
| of aerated magneſia - - | 12½ |
| of vitriolated magneſia - - - | 859½ |
| of ſalited magneſia - - | 21¾ |
| | 922¾ |

The aerial fluid expelled by heat amounts to little more than ſix cubic inches, nearly four of which are aerial acid; and the remainder pure air.

(F) As 100 cubic inches of aerial acid can diſſolve no more than 27 grains of aerated lime in a kanne of water (ſee Treatiſe on Aerial Acid), 4 cubic inches can ſcarcely take up more than one; the greateſt part, therefore, of the aerated lime found in Seydſchutz water is mechanically ſuſpended in it, by means of the minuteneſs of its parts.

Salited magneſia may be partly decompoſed, by bare evaporation to dryneſs—hence we muſt not conclude, that all the magneſia which, upon analyſis, is found in a diſengaged ſtate, has always exiſted in the water in that ſame ſtate, but rather that it has been united with marine acid in greater or leſs quantity, according to the degree of heat applied in the evaporation. Salited magneſia is eaſily diſcovered, as it diſſolves ſlowly, and without efferveſcence, in acids.

## § III. *The Appearances of Seydſchutz Water with Precipitants.*

(A) Tincture of turnſole, made with diſtilled water, and ſo diluted as to appear diſtinctly (*b*)

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(*b*) On Aerial Acid, § VI.

ring its ſolution. If the mixture be ſuffered to ſtand quiet, a whitiſh cloud is formed over the turbith mineral, which is no other than a ſalited mercury.

(K) Corroſive ſublimate precipitates ſlowly a white ſediment, which conſiſts of an aerated (e) mercurial calx, and is readily precipitated by means of lime or magneſia aerated.

(L) Saccharum ſaturni, or, to ſpeak more properly, acetated lead, precipitates a white powder, which is a vitriol of lead, occaſioned by the decompoſition of vitriolated magneſia. The whiteneſs of this powder demonſtrates the abſence of ſulphureous matter.

(M) Martial vitriol is converted into an ochre, during its ſolution in Seydſchutz water, becauſe the aerated lime and magneſia ſeparate the vitriolic acid, and the pure air contained in the water dephlogiſticates the metallic baſe: vitriol in like manner depoſits an ochre in a bottle full, and well ſtopped. All theſe phænomena, therefore, demonſtrate the preſence of the ſeveral matters which were before aſſerted to be contained in Seydſchutz water.

## § IV. *Specific Gravity.*

I compared the ſpecific gravity of Seydſchutz water with that of the beſt common water, (diſtilled by a ſlow fire), and that in an heat of 15°: repeated experiments determined its ſpecific gravity to be to that of diſtilled water as 1,0060.

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(e) On Aerial Acid, § XII.

Although the ſpecific gravity of a ſolution is rarely agreeable to that of the ingredients taken together, the following compariſon will not be without its uſe:

A kanne of the pureſt ſnow-water, diſtilled ſlowly, is nearly equal in weight to 42,250 grains; the ſame meaſure of Seydſchutz water weighs 42,503; the difference therefore is 253 grains. But in § 11. we got, from a kanne of Seydſchutz water, no leſs than 922¾ grains, which is nearly four times the laſt number.—We muſt now take into conſideration the water of the cryſtals, which in 100 of aerated lime makes 11; of vitriolated lime 22; of aerated magneſia 30; of vitriolated magneſia 48; and of ſalited magneſia nearly 40.—Hence, a calculation being made, we find the water of cryſtallization of the ſubſtances contained in a kanne of Seydſchutz water to be 431 grains. Hence, 923 — 431 = 492; but 492 — 253 = 239; which ſtill ſhews a conſiderable difference: but this difference will ſoon vaniſh, ſuppoſing the ſpecific gravity of the ſalts to be in general 2; and that, conformable to the moſt accurate experiments, no mutual penetration takes place;—for 492 grains of ſalts, put into a kanne of diſtilled water, diſplace only ſo much water as is equal to $\frac{492}{2} = 246$; the weight therefore of a kanne of diſtilled water, in which 492 grains of ſalts are diſſolved $= 42{,}250 + 246 = 42{,}496$; but $42{,}503 - 42{,}496 = 7$. Now, ſince 6 cubic inches of atmoſpheric acid weigh about 3 grains, we have at length $7 - 3 = 4$ grains, indicating nearly how much has been loſt, during the operation, on the filters and veſſels.

## § V. *Analyſis of Seltzer Water.*

### *Principles collected by Evaporation.*

Seltzer water, beſides a ſubtile pungent acidity, excites upon the tongue a taſte gently ſalt, and mildly alkaline.

(A) By quick boiling, it depoſits an aerated lime, which had been diſſolved by means of ſuperabundant aerial acid;—this, collected on a filter, is found to contain ſcarce any aerated magneſia, as this laſt is both more eaſily diſſolved, and retains the quantity of volatile menſtruum neceſſary for ſolution more obſtinately than the lime does.

(B) By a continued evaporation, the magneſia ſeparates; but as it continues to ſeparate during the whole evaporation, it cannot be collected by filtration; we muſt therefore evaporate to dryneſs, waſh the reſiduum with hot diſtilled water, and at length the magneſia will remain alone at the bottom.

(C) The ſolution which is obtained by warm water yields, on cryſtallization, two ſalts; the one an alkali, which, with vitriolic acid, forms a true and pure Glauber's ſalt, and is therefore no other than genuine mineral alkali; the other cubic, agreeing perfectly with pure culinary ſalt.

Salited magneſia, which almoſt always accompanies culinary ſalt, is in this caſe not to be found; nor could it poſſibly be ſo, on account of the diſengaged alkali.

(D) The weights of the ſeveral matters contained in a kanne of Seltzer water are as ſet forth in the following table.

| | grains. |
|---|---|
| Aerated lime, - - | 17 |
| Aerated magneſia, - - | 29½ |
| Cryſtallized mineral alkali, - | 24 |
| Common ſalt, - - | 109½ |
| | 180 |

The aerial fluid ſometimes amounts to 60 cubic inches, which is almoſt all aerial acid; for the pure air ſcarcely exceeds a ſingle cubic inch.

## § VI. *The Habitudes of Seltzer Water with Precipitants.*

(A) Tincture of turnſole grows red upon the addition of a ſmall portion of Seltzer water; but in the open air the blue colour gradually returns—a change which takes place immediately upon the application of heat.

Paper tinged with tincture of turnſole is rendered more diſtinctly blue by this water; that tinged by Brazil wood grows blue; and that tinged yellow by turmeric is but little changed: however, if the ingredients be reduced to a ſmall ſpace by evaporation, this paper aſſumes a browniſh red.

(B) Tincture of galls and phlogiſticated alkali produce no ſigns of any thing metallic.

(C) Cryſtallized vegetable alkali produces no effect; but the cauſtic alkali precipitates a white powder, which efferveſces with vitriolic acid, and forms a gypſum: this therefore is aerated lime, deprived of the portion of volatile menſtruum neceſſary for its ſolution.

(D) The ſtrong acids occaſion a great number of bubbles, which conſiſt of the aerial acid expelled from the alkali and the aerated earths.

(E) Acid of ſugar immediately ſeizes the lime, and falls to the bottom.

(F) Salited terra ponderoſa precipitates no ſpathum ponderoſum, which moſt evidently ſhews the abſence of vitriolic acid; for that acid attracts terra ponderoſa with ſuch force, that, deſerting every other baſe, it unites with that earth in the form of nearly inſoluble atoms.

(G) Salited lime does not precipitate a calcareous powder until after a day or two.—This precipitate is occaſioned by the mineral alkali which the aerial acid, ſo long as it remains in ſufficient quantity, holds ſuſpended.

(H) Alum is decompoſed in like manner by the diſengaged alkali.

(I) Solution of ſilver renders Seltzer water immediately milky, being partly converted into a ſalited ſilver, partly yielding its acid to the alkaline ſalt.

(K) Solution of mercury, made without heat, in nitrous acid, occaſions a copious white precipitate;—the ſolution made by heat cauſes a yellow one.

(L) Corroſive ſublimate precipitates a white powder, but not until after ſome days.—If about $\frac{1}{3}$ of the water be diſſipated by evaporation before the ſublimate is added, no change is obſerved; but after a few days blackiſh cryſtals appear by degrees. Of theſe cryſtals we have already treated, (on Aerial Acid, § XII).

(M) Cryſtallized ſaccharum ſaturni immediately precipitates a white ſediment, which is all ſoluble in vinegar.—The ſame happens with lead, either united with marine acid, or precipitated by fixed alkali. Vitriol of lead is not ſoluble in vinegar.

(N) Vitriol of iron depoſits a white ſediment, which gradually grows yellow, even in a bottle full and well ſtopped.

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(E) Acid of ſugar immediately ſeizes the lime, and falls to the bottom.

(F) Salited terra ponderoſa precipitates no ſpathum ponderoſum, which moſt evidently ſhews the abſence of vitriolic acid; for that acid attracts terra ponderoſa with ſuch force, that, deſerting every other baſe, it unites with that earth in the form of nearly inſoluble atoms.

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(L) Corroſive ſublimate precipitates a white powder, but not until after ſome days.—If about $\frac{1}{3}$ of the water be diſſipated by evaporation before the ſublimate is added, no change is obſerved; but after a few days blackiſh cryſtals appear by degrees. Of theſe cryſtals we have already treated, (on Aerial Acid, § XII).

(M) Cryſtallized ſaccharum ſaturni immediately precipitates a white ſediment, which is all ſoluble in vinegar.—The ſame happens with lead, either united with marine acid, or precipitated by fixed alkali. Vitriol of lead is not ſoluble in vinegar.

(N) Vitriol of iron depoſits a white ſediment, which gradually grows yellow, even in a bottle full and well ſtopped.

## § VII. *Specific Gravity of Seltzer Water.*

In a moderate heat, I found the ſpecific gravity of Seltzer water to be 1,0027; hence the weight of one kanne ſhould be 42,363 grains, which, calculating from the ingredients, will be 42,250 + $\frac{180-31}{2}$ = 42,324½, as the water forms about 31 grains, 64 to every hundred of alkali, allowing 6 to the ſea-ſalt, and the reſt as in § IV. The weight of 60 cubic inches of aerial acid is nearly 30 grains; therefore 42,363 — 42,324½ — 30 = 8½; the difference of weights of a kanne, one of which is computed by the ſpecific gravity, the other from the quantity of the heterogeneous contents.

## § VIII. *Analyſis of Spa Water.*

### *Principles collected by Evaporation.*

Spa water has a martial ſub-alkaleſcent, mild, and gently pungent taſte. On expoſure to the open air for ſome hours, it contracts a ſhining variegated pellicle on the ſurface.

(A) By quick boiling it ſeparates a ferruginous powder; let this, collected by filtration, and a little roaſted, be put into vinegar; for this menſtruum diſſolves the earthy parts, leaving the dephlogiſticated iron untouched.—Whatever is afterwards precipitated from the vinegar by an alkali is no other than an aerated lime.

(B) During the whole progreſs of evaporation, even to the very end, a white powder is continually ſeparating, which may be obtained from the dry reſiduum by ſufficient waſhing carefully conducted. This generally diſſolves in vinegar, with effervеſcence, and is found to poſſeſs the properties of aerated magneſia; but ſometimes a part remains untouched; this is gypſum, and rarely amounts to a grain in a kanne.

(C) The water with which the reſiduum has been waſhed, on cryſtallizing, exhibits the mineral alkali, mixed with a few cubes of common ſalt. This alkali, united with vitriolic acid, forms a genuine Glauber's ſalt, ſometimes intermixed with a few cryſtals, reſembling vitriolated vegetable alkali.

(D) The experiments hitherto made ſhew, that a kanne of Spa water contains,

| | grains. |
|---|---|
| of aerated iron, - - | 3¼ |
| of aerated lime, - | 8½ |
| of aerated magneſia, - | 20 |
| of cryſtallized mineral alkali, | 8½ |
| of common ſalt, - - | 1 |
| | 41¼ |

The aerial fluid collected rarely amounts to 45 cubic inches; which is all aerial acid, and is abſorbed by water.—I found not any pure air, and perhaps it could not long exiſt together with aerated iron, as the pure air ſeizes the phlogiſton, and flies off with it.

## § IX. *Habitudes of Spa Water with Precipitants.*

(A) One part of Spa water generally reddens 25 of tincture of turnſole. The paper tinged by turnſole is rendered of a more vivid blue; that tinged by fernambucum is made blue; but paper coloured by turmeric is ſcarcely changed, until the water has been a good deal reduced by evaporation.

(B) A ſingle drop of tincture of galls renders Spa water purple; and phlogiſticated alkali produces, though ſlowly, Pruſſian blue.—Spa water, after boiling, does not exhibit the ſmalleſt ſign of iron, either by theſe precipitants, or by any other method.

(C) Cauſtic fixed alkali, after 24 hours, ſeparates, though ſparingly, a white calcareous powder. The cryſtallized alkali has no other effect than to deprive the water of its pungent flavour.

(D) Concentrated acids occaſion a great quantity of bubbles.

(E) Saccharated vegetable alkali, as alſo acid of ſugar alone, precipitates lime but ſparingly.

(F) Salited terra ponderoſa very rarely ſeparates any thing, and when it does, it is very ſlowly; which indicates either the abſence of vitriolic acid, or that its quantity is extremely ſmall.

(G) Salited lime, after 24 hours, is precipitated by the fixed alkali of the water.

(H) Alum depoſits its earth.

(I) Solution of ſilver throws down a fine white powder.

(K) Solution of mercury, made without heat, yields a yellowiſh white precipitate; that made with heat a browniſh yellow.

(L) Corroſive ſublimate, after 24 hours, ſeparates a grey powder, which, if the water be previouſly concentrated by evaporation, is of a browniſh yellow.

(M) Acetated lead forms a white precipitate.

(N) Martial vitriol yields a white powder, which gradually grows yellow.

## § X. *Specific gravity of Spa Water.*

In an heat of 15° the ſpecific gravity of Spa water is 1,0010, hence the weight of one kanne ſhould be 42,292 grains;—but the water of the reſiduum is about $14\frac{1}{2}$, and the weight of 45 cubic inches of atmoſpheric acid $= 22\frac{1}{2}$;—therefore $42{,}292 - 42{,}250 + \frac{41-12}{2} + 22\frac{1}{2} = 5$; which is the difference ſought.

§ XI.

## § XI. *Analyſis of Pyrmont Water.*

### *Principles collected by Evaporation.*

Pyrmont water poſſeſſes a moſt agreeable ſubacescent, pungent flavour, not unlike that of Champaigne wine, but at the ſame time martial, and a little bitteriſh; in the open air, it contracts a pellicle like the Spa water.

(A) During ebullition aerated iron, together with aerated lime, is ſeparated; the former may be eaſily ſeparated from the latter, by means of vinegar, as above deſcribed (VIII. A).

(B) After filtration, let the evaporation be continued to dryneſs; let the reſiduum, waſhed with a ſufficient quantity of diſtilled water, be put into vinegar: the part thus diſſolved ſhews the properties of magneſia; that which remains untouched is found to be gypſum.

(C) The water with which the reſiduum has been waſhed, being evaporated, exhibits at firſt true vitriolated magneſia; but towards the end, magneſia mixed with common ſalt, which may in ſome degree be ſeparated by conducting the evaporation very ſlowly.

(D) All the ingredients being carefully weighed, there are found in each kanne of Pyrmont water,

grains.

| | grains. |
|---|---|
| of aerated iron - | $3\frac{1}{4}$ |
| of aerated lime - | 20 |
| of vitriolated lime - | $38\frac{1}{2}$ |
| of aerated magneſia - | 45 |
| of vitriolated magneſia - | 25 |
| of common ſalt - - | 7 |
| | $138\frac{3}{4}$ |

The aerial fluid collected ſometimes amounts to more than 90 cubic inches, and conſiſts entirely of aerial acid ; in general, however, the quantity of aerial acid is much ſmaller.

### § XII. *Appearances of Pyrmont Water with Precipitants.*

(A) Pyrmont water communicates a deeper red tinge to tincture of turnſole than Spa water does. The paper ſtained by turnſole has its colour heightened; that with fernambucum grows blue; that with turmeric is not changed, even though the water has been much evaporated.

(B) Tincture of galls and phlogiſticated alkali ſoon diſcover iron; but the water, after boiling, ſhews no ſigns of that metal.

(C) A ſingle drop of cauſtic fixed alkali, throws down a white earth, which, on examination, exhibits the qualities of magneſia.

(D) Concentrated acids occaſion an efferveſcence.

(E) Acid of ſugar precipitates lime quickly and copiouſly.

(F) Salited terra ponderoſa indicates vitriolic acid, for a ſpathum ponderoſum precipitates.

(G) Salited lime occaſions a gypſeous precipitate, which after 24 hours becomes viſible.

(H) Alum is decompoſed, even after the lime is ſeparated; this effect is therefore produced by the aerated magneſia.

(I) Solution of ſilver occaſions a milky turbidneſs.

(K) Solution of mercury, made without heat, occaſions a whitiſh yellow precipitate; that made with heat, exhibits a more copious ſediment, of a deeper yellow; in both caſes, if the ſolution be gently dropped in, and the water ſuffered to ſtand quiet, a white cloud is ſuſpended over the bottom of the veſſel, which indicates a ſalited mercury.

(L) Corroſive ſublimate after 24 hours produces an ochry precipitate, ſoluble in vitriolic acid. Pyrmont water, much evaporated, depoſits a white powder, upon the addition of corroſive ſublimate.

(M) Acetated lead yields a white powder, great part of which reſiſts the action of vinegar.

(N) Martial vitriol yields at once a white precipitate, which grows yellow, though ſlowly.

§ XIII.

## § XIII. *Specific Gravity of Pyrmont Water.*

The ſpecific gravity of Pyrmont water is found, in a moderate heat, to be 1,0024; the weight, therefore, of one kanne is 42,351 grains; but as the water of the reſiduum is $36\frac{3}{4}$, and the weight of 90 cubic inches of atmoſpheric acid is 45, 42,250 $+ \frac{138\frac{3}{4} - 36\frac{3}{4}}{2} + 45 = 5$; the difference by which the weight of a kanne, computed by its ſpecific gravity, exceeds the weight deduced from the quantity of heterogeneous contents.

## § XIV. *Compariſon of the Waters above examined.*

That we may have, in one ſynoptical view, the contents of all theſe waters, we ſhall ſet the whole in order in the following Table.

TABLE

| | Seydſchutz. | Seltzer. | Spa. | Pyrmont. |
|---|---|---|---|---|
| Aerated lime, | 4½ | 17 | 8½ | 20 |
| Vitriolated lime, | 24½ | — | — | 38½ |
| Aerated magneſia, | 12½ | 29½ | 20 | 45 |
| Vitriolated magneſia, | 859½ | — | — | 25 |
| Salited magneſia, | 21¾ | | | |
| Aerated mineral alkali, | — | 24 | 8½ | |
| Salited mineral alkali, | — | 109½ | 1 | 7 |
| Aerated iron, | — | — | 3¼ | 3¼ |
| Sum total, | 922¾ | 180 | 41¼ | 138¾ |
| Greateſt quantity of aerial acid, in cubic inches, | 4 | 60 | 45 | 90 |
| Pure air, | 2 | 1 | | |
| Specific gravity, | 1,0060 | 1,0027 | 1,0010 | 1,0024 |

## § XV. *Conjecture concerning the Way in which Nature prepares theſe Waters.*

Among the waters now examined, the Seydſchutz contains ſcarcely more aerial acid than common fountain water: to account, therefore, for the origin of this water, ſuch a ſituation of its channels as may conduct it through ſtrata of aerated lime, &c. is ſufficient; and theſe ſtrata are found in many places; the water paſſing through theſe by degrees takes up the quantity which is found in it as above.

The three others poſſeſs ſo large a quantity of aerial acid, that they could not have received it from the atmoſphere. This elaſtic vapour is abundantly extricated in three different ways (on Aerial Acid, § 11.) namely, by fermentation, by fire, and by the action of a more powerful acid: the firſt of theſe can ſcarcely be ſuppoſed to take place in the bowels of the earth; but I ſee no reaſon why the other two may not operate, either jointly or ſeparately:—Thus ſubterranean fire expels the aerial acid from calcareous earth, and ſtill more readily from magneſia; and it is the more readily abſorbed by the water which it meets with, in proportion as that water is the more divided into channels, as it is the more cold, and the more compreſſed by the ſubtile elaſtic fluid. Nor is the third method attended with any difficulty; for although, on the ſurface of the earth, water ſcarcely ever contains an uncombined mineral acid, yet in the boſom of the earth, the vitriolic acid muſt be often ſet free by the deflagration of ſulphur; and perhaps the marine acid may be extricated from ſalited lime and magneſia by ſubterraneous fire.—We ſhall ſoon ſee the effects of earthy and metallic ſalts, when decompoſed by mineral alkali or alkaline earths.

Let us firſt conſider the Seltzer water; and begin by enquiring whether it owes its aerial acid (which is the chief point in queſtion, the other ingredients being found in the boſom of the earth) to the decompoſition of middle ſalts by an alkali; or to alkalis directly diſſolved in acids; or, finally, to the extrication of that elaſtic fluid by ſubterraneous heat alone.

To examine the firſt ſuppoſition, let us ſuppoſe that water loaded with ſalited lime and magneſia meets with an aerated alkali; now a kanne of Seltzer water contains 109½ grains of common ſalt, in which there are about 46 of pure mineral alkali; and theſe require about 37 of aerial acid to ſaturate them; that is, 74 cubic inches, becauſe each cubic inch weighs about half a grain: but 45½ grains of pure lime may be precipitated by that quantity of alkaline ſalt; and theſe immediately abſorb about 28 grains of aerial acid. In the ſame manner, by an equal quantity, upwards of 35 grains of pure magneſia are precipitated; and this quantity, in precipitating, carries along with it at leaſt 19½ grains of aerial acid. Making a calculation, therefore, it appears, that in the firſt caſe there only remain to ſaturate the water 37—28 = 9 grains = 18 cubic inches of aerial acid, which is not ſufficient for the purpoſe (§ XIV); and in the caſe of the magneſia 37 — 19½ = 17½ grains = 35 cubic inches; a quantity far too ſmall (§ XIV). The common ſalt, therefore, which is preſent in Seltzer water, does not ſeem to originate in this way, ſuppoſing that the water at once receives the 60 cubic inches of aerial acid; but if the water contains ſo much marine acid as is ſufficient for the immediate production of 109 grains of common ſalt, the end will be completely obtained, as all the 74 cubic inches can without diminution be applied to that purpoſe. There is no doubt but this may take place, if the aerial acid be expelled by fire.—We now proceed to conſider the two martial waters.

Pyrmont water contains 7 grains of common ſalt in a kanne; which, if we ſuppoſe them generated from ſalited magneſia, precipitated by mineral alkali, will give ſcarce more than 3 cubic inches for aerating the water. The vitriolated lime and magneſia are of no uſe in this proceſs, unleſs generated in the water itſelf, either by means of a diſengaged vitriolic acid, or, as is more probable, by the decompoſition of martial vitriol.

A kanne of Pyrmont water contains 38¼ grains of gypſum, and 25 of vitriolated magneſia: theſe two ſalts together contain about as much vitriolic acid as 67 grains of cryſtallized green vitriol. Let us then ſuppoſe, that water, impregnated with this quantity of vitriol, meets with 20½ grains of aerated lime, and about 11 grains of aerated magneſia, and the above-mentioned ſalts will appear; and during this operation the former baſe gives out 16½ cubic inches of aerial acid, and the latter 6; but 22½ cubic inches ſcarce amount to a fourth part of the neceſſary bulk, even adding 7, which are got from the common ſalt, ſuppoſing it to be generated in the water;—a great deficiency, therefore, ſtill remains, ſo that we muſt try another method.

Let us ſuppoſe a kanne of water loaded with 276 grains of vitriol (which is by no means extravagant, as that quantity of water can take up upwards of 6,000 grains) meets with 235 grains of aerated lime; in this caſe not only 100 cubic inches of aerial acid will be extricated, but enough of the iron and gypſum will be diſſolved to saturate the water. Thus, then, by the addition of 25 grains of vitriolated magneſia, we have a complete Pyrmont water.

It is otherwiſe with the Spa water—this is very poor with reſpect to the quantity of ſaline contents; and, with regard to the nature of theſe ſalts, is ſuch, as to require a quantity of aerial acid, that has been extricated externally;—in this water, beſides the mineral alkali, lime, magneſia, and iron, (all of which are united with aerial acid), there is nothing contained, except a ſingle grain of common ſalt—hence it is plain, that this water cannot be aerated, either by the ſaturation of marine acid, or by the decompoſition of middle ſalts in the water itſelf. Now, in the neighbourhood of Spa there are no veſtiges of ſubterraneous fire; how then does the water acquire the aerial acid in the boſom of the earth? We firſt obſerve, that veſtiges of ſubterranean fire, once abundantly manifeſt, are by lapſe of time often ſo defaced, as to be ſcarcely diſcernible; beſides, a degree of ſubterraneous fire, ſufficient to extricate this ſubtile acid, may eaſily exiſt, without producing earthquakes or eruptions of any kind, and that for any length of time, provided the cauſes be ſo tempered that the effects may remain the ſame; neither is it neceſſary that the efficient cauſe ſhould be in the neighbourhood, for the ſuperficial ſtrata of this globe are perforated in almoſt every direction, ſo that the elaſtic fluid may come through a variety of channels, from places very remote. In the preſent inſtance it appears, that the aerial acid muſt have paſſed through a length of way, as it is found to have depoſited all its heat; but martial vitriol alone, diſſolved in water, and penetrating ſtrata, which contain either alkaline ſalts, lime, or magneſia, may, by decompoſition, extricate a ſufficient quantity of aerial acid; which being conducted to a great diſtance from the place of its origin, may be ſo united with water, that ſuch water ſhall not exhibit the ſlighteſt marks of thoſe ſubſtances which contributed to its impregnation.

I have ſometimes found a ſmall portion of gypſum in Spa water, in the quantity of about one grain to a kanne; but how can this be, if we ſuppoſe a diſengaged mineral alkali (or rather an alkali only, united with aerial acid) to be preſent, as ſuch an alkali attracts the vitriolic acid more powerfully than lime does? We may obſerve firſt, that there is only $\frac{1}{100}$ of a grain of gypſum in a cubic inch of water; and of the mineral alkali, no more than $\frac{1}{10}$ of a grain; for the combination of mineral alkali and aerial acid is not ſpontaneouſly decompoſed: ſubſtances, therefore, which are ſo thinly ſcattered through the water, may reaſonably be ſuppoſed to act very ſlowly upon each other, eſpecially as the alkali, when aerated, is very inactive. An example will ſhew how the activity of ſubſtances is repreſſed by aerial acid:—let vitriolated magneſia be diſſolved in water; drop in a little lime-water, and inſtantly the magneſia falls to the bottom, having yielded its acid to the lime; but if pieces of chalk or calcareous ſpar be put into the ſolution, no decompoſition can be produced, even by boiling: hence we ſee how, in Seydſchutz water, vitriolated magneſia may exiſt, together with aerated lime.

Beſides, moſt commonly, there is no gypſum found in Spa water: whether this happens becauſe the water is taken from different ſprings, or whether the number of principles is not always the ſame in the ſame ſpring, I have no doubt but that the proportion of the ingredients does frequently vary, and I am confirmed in this opinion by experience, and the nature of the thing itſelf.

### § XVI. *Whether the Waters above examined be imitable by Art.*

The completion of any analyſis can by no other means be ſo clearly evinced as by producing ſynthetically a perfect imitation of the thing analyſed; as it thence appears that we have not only diſcovered the primary principles, but alſo the true method of uniting them. We are now to try what can be done in the preſent caſe. From what has been ſaid, it appears, that the art of preparing medicated waters comprehends two circumſtances of moment; firſt, it is requiſite that water, pure, and totally deſtitute of every ſort of taſte, be as it were vivified by aerial acid, which conſtitutes the genuine mineral ſpirit as it is called; by this the water acquires a grateful, ſubtile, penetrating taſte, together with ſingular virtues; but the efficacy of this acid muſt be ſeconded by other groſſer ſubſtances, which determine the peculiar nature of the water; ſo that one ſhall reſemble Seltzer, another Spa, and a third Pyrmont water;—the firſt of theſe differs much from the other two in its nature and properties, nor do the two chalybeate waters altogether agree. It is not therefore ſufficient, for the imitation of theſe mineral waters, to be acquainted with the method of impregnating water with aerial acid: the principles proper to each, from whence their ſpecific virtue and efficacy is derived, muſt alſo be accurately underſtood.

Many perſons are firmly perſuaded, that in the natural production of medicated waters, there takes place a certain degree of fermentation, as they are pleaſed to call it, which can never be imitated by art: but thoſe who are well acquainted with the ſubject are of a very different opinion. The queſtion is entirely reducible to this, viz. to diſcover accurately the heterogeneous contents of thoſe waters, and to unite thoſe heterogeneous matters with pure water It can be of little conſequence whether the water diſperſed through the bowels of the earth, by paſſing through certain ſtrata extract certain materials, or whether thoſe very materials be artificially added in proper quantity:—the hand that ſupplies the ingredients can make no difference in the reſult.

## § XVII. *The Method of Aerating Water.*

The moſt ſimple method is that which Venel has employed, and I believe is the ſame as that frequently employed by nature for the ſame purpoſe (§ XVI.): but in order to generate in water the proper neutral or middle ſalts, a more laborious and cautious management is neceſſary; as we are not in poſſeſſion of an eaſy and commodious method of meaſuring either the ſtrength of the menſtrua, or the quantities neceſſary for ſaturating them.—The following is the method which I at firſt employed:—

A B is a glaſs veſſel, ſomewhat (fig. ii.) more than half filled with water, and chalk coarſely powdered; the tube A C D is ſo fitted to the mouth of the bottle, that not the leaſt air can eſcape. The tube E, in the ſide of the bottle, is accurately cloſed by the ſtopper F, as ſoon as ſome drops of vitriolic acid have been poured in: this acid, as ſoon as it falls, begins to expel the weaker aerial acid from the chalk; which, riſing in the form of an elaſtic fluid, is conducted by the tube to the bottom of the water in the veſſel G H: this veſſel is choſen long and narrow, that the aerial acid may be more completely abſorbed in its paſſage through the water. A wet bladder is tied round the neck of the bottle G H, and the tube, ſo as to confine the aerial acid, which would otherwiſe eſcape:

ſcape: this reſiſtance, however, muſt not be too great, as in that caſe no aerial acid will be produced, (on Aerial Acid, § 11.). The eſcape of the aerial acid may therefore be regulated by a pin-hole in the bladder; as ſoon as the effervеſcence ceaſes, more acid is to be poured in, through the tube, and this repeated until the water has received the proper quantity of aerial acid, which may be determined by the taſte, or more accurately by tincture of turnſole. In this manner I firſt prepared aerated water; but it may be done much more commodiouſly by the funnel O, which, according to Mr Lavoiſier's method, is ſo ſhut by the glaſs rod P, that the vitriolic acid falls down ſpontaneouſly and gradually.—I ſometimes have employed a ſmall fermenting maſs (fig. vii. tab. 2.), and that with the beſt ſucceſs; but after I had learned, from the writings of Dr Prieſtly, the advantage ariſing from agitating the water, I effected this purpoſe in two more eaſy ways.

(A) Fig. iv. will explain the firſt of theſe methods better than any verbal deſcription. A B is a glaſs bottle, fitted with a lateral tube, and a glaſs ſtopper; in this bottle an effervеſcence is produced by means of chalk and vitriolic acid: E is a common glaſs bottle, filled with the pureſt water, and then ſtopped by a cork, ſo cloſely that it cannot admit any air; it is then inverted, and ſet in a groove, cut in the board G F, laid acroſs the veſſel H I, filled with water; the cork is then taken out, and the aerial acid expelled by the vitriolic is conducted into the bottle by the tube A C D: the glaſs tube L N O paſſes through the cork: P Q is alſo made of glaſs, and is fitted to the former by the intervention of the tube O P, which is made of elaſtic reſin, and tied to both, (this might be made of flexible leather, but where the ſides croſs, it muſt be ſewed only half through, otherwiſe the air will eſcape through the holes made by the needle): the joint O P is made flexible, that the bottle A B may be ſhaken, by which the extrication of aerial acid is much expedited; but this muſt be done gently, leſt ſome of the chalk ſhould enter the tube A C, and mix with the water. For the ſame reaſon, only a ſmall quantity of vitriolic acid is to be added at one time; for if too much be added, ſo violent an effervеſcence will be occaſioned, as to carry over into the tube a quantity of the chalk: it is neceſſary to obſerve, that not the ſmalleſt cranny ſhould be left open for the eſcape of aerial acid; therefore the ſtopper of the lateral tube muſt be cloſely fitted, and every part about the neck of the bottle A B, and tube, completely ſhut up: the extremity Q may be eaſily put in and taken out of the bottle, by the forceps, fig. vi.

The apparatus being prepared, I impregnate the water in the following manner:—I fill the bottle ſomewhat more than half with aerial acid; this being done, I let fall to the bottom of the veſſel the ſaucer K; I then cautiouſly remove the bottle from the groove in the board, keeping its mouth ſtill under the ſurface of the water, and ſetting its mouth upon the ſaucer K, I agitate it violently for ſome minutes: during this operation the empty ſpace in the bottle diminiſhes, the water, by agitation, preſenting a larger ſurface of contact to the aerial acid, which is therefore more readily abſorbed; the bottle, however, cannot be entirely filled the firſt time, as ſome portion of common air remains, which will not unite with water; I therefore cork the bottle under the ſurface of the water, turn it up, and fill the empty ſpace with water; I again invert the bottle in the water, half fill it again with aerial acid, agitate it as before, and then generally obtain it full. As the water expelled from the bottle is diluted with that in the diſh, it is neceſſarily the leſs impregnated when it re-enters the bottle. If, therefore, the water is to be ſaturated, in which proceſs it takes up nearly its own bulk, (on Aerial Acid, IV.), the above-mentioned operation muſt be repeated a third time; and hence may eaſily be deduced a method of impregnating water in any given leſſer proportion.

It is in general to be obſerved, that the colder water is, the more aerial acid will it abſorb; therefore this operation ſhould be performed in a cool place, and the body of the bottle handled as little as may be.

I make uſe occaſionally of bottles of different ſizes, generally ſuch as contain half a kanne, but ſometimes (for expedition ſake) thoſe of 2, 3, or 4 kannes; but the larger are both inconvenient, on account of their weight, and are liable either to be broken themſelves or to break the ſaucer, unleſs handled with caution.

By this method a bottle of water may be ſaturated in about ten minutes: if the bottle, half filled with aerial acid, be ſuffered to ſtand inverted upon the board, the water will, in a cool place, riſe ſpontaneouſly without any agitation; but this will happen ſlowly, as before obſerved.

(B) The other method is much more eaſy, and impregnates a large quantity at one time, but is attended with this inconvenience, that it requires a very large fermenting maſs: when this can be had, let a veſſel be prepared, ſimilar to that in which the maſs is ſet to ferment, but of ſmaller diameter, ſo that the veſſel which holds the fermenting maſs may contain it; let its height be ſo adjuſted to the empty ſpace in the larger veſſel, that when the bottom of the leſſer touches the fermenting maſs, its upper edge may ſtand three or four inches at leaſt beneath the upper edge of the larger veſſel.

In the middle of this veſſel, let an axis be erected perpendicularly, ſo that, by means of an handle, it may be turned round horizontally; let there be faſtened to this axis three or four wooden plates, plate muſt be poliſhed afreſh as often as it loſes its ſplendour.

By the method juſt deſcribed waters are obtainen, agreeing both in flavour and virtue with thoſe brought from foreign countries; but as ſome of the ſubſtances contained are juſtly eſteemed of a ſuſpicious nature, I am of opinion that they ſhould by all means be omitted: theſe are the calcareous and gypſeous matters; and I am perſuaded that no perſon will imagine that chalk or gypſum can contribute to the ſalubrity of waters; but that, on the contrary, they may give occaſion to grievous obſtructions. The Pyrmont water contains theſe ſubſtances in conſiderable quantity, and for that reaſon is hurtful to many conſtitutions: for twelve kannes of this water (which is the quantity uſually taken in twenty-four days) contain half an ounce of aerated lime, and an ounce and a half of gypſum—a load which few ſtomachs are able to bear.

As to the magneſia, I do not indeed conſider it as noxious; but as it diſſolves ſlowly, and whatever effect it has may be eaſily ſupplied in another way, I omit it; eſpecially as experience ſhews that the waters thus corrected are equal, if not ſuperior, both in taſte and virtue, to the natural waters.—I generally make uſe of water fully impregnated with aerial acid.

The imported waters which have been examined have no doubt ſuffered ſome change during the voyage.—The experienced Seip relates, that a phlogiſticated vitriolic acid, and a true ſulphur, may be extracted from the vitriolated magneſia of Pyrmont water, by diſtillation, without any addition. In order to obtain half a pound of this vitriolated magneſia (which is neceſſary for his experiment) we muſt evaporate upwards of 115 kannes of the water, which I have never had an opportunity of doing;—I have, however, tried ſmaller quantities, but never could diſcover the ſmalleſt particle of the ſubſtances he mentions:—perhaps the magneſia which is united with phlogiſticated vitriolic acid in the freſh water, loſes the inflammable principle during the voyage; ſo that, on its arrival in Sweden, it retains little or none of it; in the ſame manner as the ſulphurated ſalt of Stahl changes by time into vitriolated vegetable alkali. This ingenious philoſopher (Seip) to whom the aerial acid was unknown, contends, that the phlogiſticated vitriolic acid is the true mineral ſpirit; that it adheres to the iron in Pyrmont water until expoſed to the air; and that then, by means of a ſtronger elective attraction, it ſeizes the magneſia, which it was not able to do in the cloſe and confined ſubterraneous paſſages.—This explanation, though approved of by many, is found, upon examination, to be quite contradictory to fact;—for, let us ſuppoſe the water loaded with a quantity of vitriol ſufficient to generate 25 grains of vitriolated magneſia, that is, containing 21 grains of martial vitriol in three cubic inches of diſtilled water; let this water be put into a bottle of ſuch a ſize that it will be quite filled by the addition of 10 grains and an half of magneſia, and let the bottle be then cloſely ſtopped; let this bottle be ſhaken from time to time, the magneſia will quickly diſappear, and in its place will be found a large quantity of ochre, of a greeniſh colour, as containing both aerial acid and a conſiderable portion of phlogiſton; and all this takes place without any motion or efferveſcence: in the ſpace of about an hour the water is found totally void of vitriol, loaded with 25 grains of vitriolated magneſia, ſaturated with aerial acid, and containing an aerated iron:—the reaſon of this is evident, 10½ grains of magneſia contain about 3 cubic inches of aerial acid, which an equal bulk of water is able to abſorb; no ſuch obſtacle therefore occurs in this caſe, much leſs in a whole kanne of water, as I have elſewhere mentioned. In the ſame inſtant, then, that the vitriolic acid expels the aerial, the water abſorbs it. The quantity of vitriol employed contains above 4½ grains of iron ſlightly calcined; now, 100 cubic inches of aerated water can only take up 3½ grains, ſo that 3 cubic inches of water can ſcarcely diſſolve more than $\frac{9}{100}$. The bottle being opened, the vitriolated magneſia may ſoon be ſeparated by alcohol; and this is the caſe in Pyrmont water; the phlogiſticated, as well as the common vitriolic acid, ſeparates the aerial acid from magneſia.—All this hypotheſis, therefore, falls to the ground, being void of foundation;—and Pyrmont water, expoſed to the air, grows turbid, and loſes its virtue, not on account of any tranſpoſition of its principles, but on account of the departure of the volatile menſtruum.

In the dry way, vitriolic acid with phlogiſton, generates ſulphur; but whence can ſo much phlogiſton be joined with the vitriolated magneſia in Pyrmont water?—if the ſeparated iron ſtill remains mixed with it, the difficulty is eaſily removed, as this metal, when ſlightly calcined, ſtill retains much phlogiſton: if, after the removal of the iron, ſulphur is produced, the cauſe of this phænomenon, being obſcure, ſhould be examined in the country where the water is produced.

## § XIX. *The Preparation of artificial medicated Waters in Sweden.*

In the year 1770, being attacked by a ſevere hæmorrhoidal colic, I was obliged to take above eighty bottles of foreign medicated waters. By theſe the ſymptoms, which were attended with excruciating pain, were ſomewhat mitigated; in the mean time I examined the nature and principles of theſe waters with the greateſt attention, as I moſt earneſtly wiſhed to be able to imitate them perfectly; for beſides their extreme dearneſs in this country, in the beginning of ſpring, when not only diſeaſes, the foundations of which have been laid during the ſeverity of the winter, prevail very much, but my complaints are alſo particularly troubleſome, theſe waters cannot be had freſh and good at any price.—I ſoon reaped the wiſhed-for fruit of my labours, for in the year following I ſubſtituted the artificial to the natural waters, and not only uſed them myſelf with ſignal advantage, but gave them to many of my friends with the like ſucceſs. All that time I uſed the method above deſcribed for impregnating water with fixed air; but, in the year 1773, I learned Dr Prieſtly's method, which, with a little alteration, I have ſince continued to practiſe.—The ſame year, in a ſhort Treatiſe on the Aerial Acid, which the Royal Academy of Sciences at Stockholm inſerted in their Acts, I mentioned in a curſory way that I had for ſome time prepared for myſelf and ſome of my friends artificial medicated waters, entirely reſembling the natural water, both in flavour and virtue.—The celebrated Baer, who then lived at Paris, took that opportunity of writing to my friend Mr Wargentin, requeſting me to deſcribe the method I purſued.—This I complied with, by ſending a Treatiſe on that ſubject to the Royal Academy of Sciences at Stockholm in 1774, which they inſerted in their Acts for the following year.

From the very nature of the thing it muſt be obvious, that an invention of this kind, however uſeful, cannot poſſibly be univerſally pleaſing.— Many who are incapable of aſcertaining or judging of the truth, will diſtruſt it, not without reaſon, on account of its novelty;—many contend, that to imitate nature is impoſſible, without conſidering, that when the component parts are thoroughly known, the ſucceſs of the proceſs cannot in any degree depend upon the hand which combines them.—Some who preſcribe, and others who ſell the foreign waters, condemn the artificial, for obvious reaſons; and not a few are urged by motives too trivial to be detailed. Beſides, the negligence of inexperienced operators or impure materials, may eaſily defeat the whole operation. The water itſelf, if it has any offenſive taſte, will retain it after the proceſs, and by that means bring the invention into diſrepute. Thoſe that are prepared in the very beſt manner, nay, the natural waters themſelves, grow vapid on the addition of a ſmall quantity of mineral alkali, though they ſtill retain uſeful properties, only the pungency of the aerial acid is in this caſe repreſſed.

— All theſe obſtacles, however, have not prevented the preparation and ſucceſsful uſe of artificial medicated waters, even in the moſt diſtant provinces of Sweden; and the uſe of ſuch waters has prevailed generally, although I only propoſed them in caſes of neceſſity, where the natural waters could not be had: and even thoſe who at firſt could not patiently hear them mentioned, now make uſe of them, and highly commend them.

In general they produce the ſame good effects as the natural waters, and in ſome inſtances even ſeem to excel them: my own health, though not perfectly eſtabliſhed, has, from the ſole uſe of them, been reſtored beyond expectation. Every year, about the middle of winter, the beginning of ſummer, and in autumn, I uſe about ſeven kannes in the ſpace of three weeks, and that in the following manner:—I firſt drink a few kannes of Seltzer water, I then uſe the Spa, which, with reſpect to the uncombined alkali, moſt nearly reſembles the Seltzer, and I always finiſh with the Pyrmont; I take no more than the third part of a kanne every day, as, by the experience of ſeveral years, I have found that a larger quantity is diſagreeable to my ſtomach.

I have alſo ſeen, with great pleaſure, many other complaints either entirely removed, or at leaſt alleviated, by theſe means. A circumſtance, which afforded me ſingular pleaſure, as I had very anxiouſly wiſhed to ſucceed in this experiment:—a boy of ſeven years old, at Upſal, had for ſome time been afflicted by a violent gout, which had baffled all remedy; in the year 1775, he uſed for a month the Seltzer water, prepared for him by his father, according to my inſtructions, and ſoon recovered perfect health, which he enjoys to this day.

A young gentleman, a ſtudent, about 23 years old, was ſo afflicted by the gout, that he could not, even by the help of a ſtick, move from one ſeat to another: he began the uſe of the artificial waters, firſt Seltzer, then Pyrmont, and recovered in the ſpace of one month.

Beſides, the intermittent fevers, which for ſome time paſt were epidemic in Sweden, were ſo obſtinate, that they refuſed to yield either to Peruvian bark, or the other uſual remedies, but were ſoon removed by the artificial waters, particularly Seltzer, unleſs the cure was impeded by errors in diet.

I paſs over innumerable other examples, which, indeed, encreaſe daily, and would require a particular deſcription; but I cannot avoid here mentioning a ſingular phænomenon:—the hæmorrhoids, with which I am afflicted, break ſpontaneouſly, while I am in health, generally every 20th day, but only diſcharge a few drops; they are, however, often ſtopped, eſpecially at the approach of cold weather, and then occaſion a number of diſtreſſing ſymptoms: to remedy theſe I find nothing ſo effectual as drinking the artificial Seltzer water; and in the courſe of eight years, during which I have been uſing it, it never failed me once; the effect is, to open the hæmorrhoids within ſix days, ſometimes on the third or fourth, upon which I immediately find relief. —I leave to the ſkilful in medicine the explanation of this phænomenon, which I have obſerved not only in myſelf, but in many others affected in the ſame way, to whom I recommended it to pay ſome attention to this circumſtance. Now, as the ſame effect in this caſe follows the uſe of the natural and the artificial Seltzer water, I cannot doubt of their identity, any more than of that of the others.

# DISSERTATION VII.

## OF THE ARTIFICIAL PREPARATION OF HOT MEDICATED WATERS.

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### § 1. *Different Species of Hot Waters.*

THE benign care of our All-wiſe Creator has not only provided for man's uſe cold medicated waters, but many hot medicinal ſprings are found in various parts of our globe; and as the uſe of the former is found not to be reſtricted, but extenſive and widely diverſified, ſo in like manner the latter are endowed with a great number of uſeful properties. Some of theſe hot waters ſeem to poſſeſs no remarkable virtue with regard to the human body, while others quickly diſpel a variety of diſeaſes in a very ſingular and extraordinary manner. Water does not ſeem capable of producing any notable effect upon the human body of itſelf; to this end it appears indiſpenſably neceſſary that it ſhould be impregnated with a certain ſubtile and elaſtic aura, which, when extricated in the primæ viæ, is not only of itſelf able to effect ſalutary changes, but alſo ſo acuates, ſtrengthens, and as it were vivifies the heterogeneous matters contained in the water, that they can penetrate to parts they otherwiſe could not reach, and poſſeſs powers which alone they could never exert. That the aerial acid performs this office in the cold medicated waters is, I imagine, eſtabliſhed beyond doubt in the foregoing Treatiſe;—it remains now to be examined, whether the ſame fluid is contained in the hot waters, or whether they are aſſiſted by an elaſtic fluid of another kind.

When we examine the medicinal hot waters in general, we find a remarkable difference obvious to the ſenſes: for ſome, ſuch as the Caroline baths in Bohemia, do not ſtrike the ſmell in any particular manner, and ſeem not to exhale any thing more than a moiſt and ſuffocating vapour; others, ſuch as thoſe of Aix, diſperſe far and wide a moſt ſubtile, ungrateful, fœtid odour, reſembling that of putrid eggs, or more exactly that which is emitted by a ſolution of ſaline hepar, eſpecially upon the addition of an acid. The former moſt certainly derive their efficacy from the aerial acid, and are therefore juſtly called aerated; but the latter are of a very different nature, and may, from their hepatic ſmell, not improperly be called hepatiſated. The nature and properties of both muſt be accurately examined, if we expect to attain any thing like exactneſs in the imitation of them. They both contain a principle ſo volatile that they loſe their chief virtue upon barely growing cold; ſo that by no means yet known can they be tranſported into foreign countries, ſtill retaining their virtue. This circumſtance has prevented me from examining theſe hot waters myſelf: but ſo much as will be ſufficient for our preſent purpoſe is to be found accurately inveſtigated, and clearly related, by the induſtry of others.

## § 11. *Hot Aerated Waters.*

That the Caroline waters, and others of the ſame ſort, abound with aerial acid, may be inferred from their taſte, and the quantity of bubbles which is occaſioned by agitating them: but other and more obvious criteria ſhew this evidently to be the caſe. This water tinges tincture of turnſole with a fugitive redneſs, and precipitates lime-water; circumſtances which, though ſingly ambiguous, yet jointly are perfectly valid; —they are ambiguous ſingly, becauſe it is thought that other acids, beſides the aerial, may occaſion a fugitive redneſs (*a*); and the precipitation of lime-water is alſo occaſioned by an aerated alkali, which is ſuppoſed, according to the laws of attraction, to yield its aerial acid to the pure lime, which therefore becomes aerated, and (*b*) precipitates; but when theſe two circumſtances are taken together, they produce full conviction; for the aerated alkali (*c*) cannot exiſt in water together with any acid, except the aerial; beſides, the air contained in theſe waters, when collected, not only produces the above-mentioned effects, but alſo ſuffocates animals, and is abſorbed by water, which thence becomes aerated. Indeed, the whole neighbourhood of theſe waters abounds ſo much with aerial acid, which breaks out in many places, that the rain and ſnow-water, from lying in cavities of the ground for a ſhort time, often acquire a grateful pungent acidity.

Theſe waters, upon cooling, ſeparate both lime and iron, after the manner of Pyrmont water, but much more quickly. We cannot wonder at the fugitive nature of the virtues of theſe waters, when we conſider how very volatile the aerial acid is, even when lodged in cold water, and how much its volatility is increaſed by heat.

The exiſtence of aerated hot waters being eſtabliſhed,

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(*a*) On Aerial Acid, § VI.

(*b*) Ibid. § XX. B.

(*c*) Analyſis of Waters, § VIII. D.

bliſhed, we now go on to the other ſpecies, the elaſtic fluid of which, though eaſily diſſipated, yet in fixity very much exceeds the aerial acid.

### § 111. *Hot hepatiſated Waters.*

The hot hepatiſated waters, although they may be aerated, and actually often are ſo (as for inſtance thoſe of Aix) may yet be eaſily diſtinguiſhed from the hot aerated waters, by the general tenor of their character, and their diſagreeable ſmell: they have the ſmell of hepar ſulphuris, and blacken ſilver, nay, a genuine ſulphur is depoſited along the channels through which they paſs; and yet the moſt accurate analyſis has not been able hitherto to diſcover in the water the moſt minute particle, either of hepar or of ſulphur —but chymiſtry is able to unfold this myſtery: for the ſaline hepar ſulphuris, upon the addition of a more powerful acid, generates a ſpecies of air, which we may call hepatic air, if with Dr Prieſtly we give the name of air to every elaſtic fluid not condenſible by cold. Waters impregnated with this kind of air reſemble the hot hepatiſated waters: the hepatic air, it is true, contains a ſulphur, but ſo expanded and ſubtilized as to eſcape the ſight, and put on the appearance of common air. A change ſuch as this can only be effected by the action of agents at once the moſt ſubtile and the moſt efficacious, and ſuch are phlogiſton and the matter of heat. I know that many philoſophers of the firſt rank are of opinion, that the phænomena of fire and heat are to be explained upon the ſuppoſition of inteſtine motion in bodies; but, upon conſidering the whole attentively, I am firmly perſuaded, and I believe the ſame is the caſe with others; that heat ariſes from the action of a diſtinct and peculiar ſubſtance, which is diſtributed through the whole corporeal world, and that in a twofold ſtate: for, firſt, we conſider this matter as free, when, in form of an elaſtic fluid continually tending to an equilibrium, it pervades all bodies denſe as well as rare. This, in proportion to its quantity, excites different degrees of heat in animals, dilates and diſpoſes all bodies to fluidity, according to certain circumſtances—thus platina, in order to be fuſed, requires it very highly concentrated, other metals leſs ſo; and mercury a quantity ſo ſmall that it is almoſt always preſent in the atmoſphere; I ſay, almoſt always, as ſome late obſervations in Siberia ſhew that there mercury has been ſometimes congealed by natural cold:—whether there can exiſt any ſuch ſtate as that of perfect privation of heat, or abſolute cold, is yet unknown. In ſuch a ſtate (ſuppoſing any ſuch to exiſt) if I miſtake not, the aerial acid itſelf muſt be congealed, as fluidity appears to depend totally upon heat.

The matter of heat, like all other material ſubſtances, is ſubjected to the law of attraction, and hence proceeds its ſtate of union with other bodies, a ſtate which inevitably occaſions many alterations in its nature and properties. By this tie ſome of its properties are obſcured, nay entirely obliterated, and new ones, before unknown, are produced; and in the ſame manner as an acid, when ſaturated with an alkali, cannot be diſtinguiſhed either by precipitation, by its taſte, or by any other of its original properties, ſo the matter of heat loſes, together with its liberty, its chief property, viz. that of producing ſenſible heat;—this power muſt, however, be conſidered as repreſſed only, not deſtroyed; for it is again reſtored in full vigour, when the bond of union which repreſſed it is broken. This may very clearly be illuſtrated by the example of water, which by a moderate privation of heat is converted into ice: now, if water heated to a determinate degree be poured on ſnow, we can, from the known heat of the two ingredients, eaſily determine what that of the mixture ought to be; but in the preſent inſtance, a deficiency is always obſerved; that is, the heat of the mixture proves to be always leſs by about 72°, than by calculation it ought to be. The reaſon ſeems to be this:—the heat of the water penetrates the ſnow quickly, expands and ſeparates the ſmall particles, and changes it from a ſolid to a fluid form: thus the diſunited particles have their ſurfaces much encreaſed. Now, water attracts the matter of heat, and that the more largely in proportion to the ſurface of contact; and ſuch parts of it as it touches very cloſely, it powerfully retains, and renders latent, ſo that it can no longer occaſion ſenſible heat; and hence the deficiency of 72°. This ſaturating portion of heat it does not loſe, except at the very point of congelation; which being then ſet free, occaſions a ſmall riſe of the thermometer, although it is quickly and irregularly attracted on account of the deficiency of the ſurrounding matter. As the degree of cold in the adjoining air increaſes, and as, on account of its elaſtic nature, it conſtantly tends to an equilibrium, it at length is ſo much rarified, that the ſaturating portion alone remains to prevent the contact of the watery particles; and when that alſo is taken away, all the mobility of the particles totally ceaſes. Undoubtedly all ſubſtances which are fuſible in fire fix a certain quantity of heat (the degree of which is yet undetermined) in the very inſtant when their particles acquire the due degree of mobility. On the other hand, while the temperature of the water is increaſing, the increaſed quantity of heat increaſes the diſtance of the minute particles, and generates elaſtic vapours: at length, when the heat arrives to the boiling point, the watery particles are ſo expanded and changed, that their ſurfaces, being wonderfully increaſed, are enabled to receive and fix a far greater quantity of heat than before;—and hence ſtriſes the cold, or diminution of heat, occaſioned by evaporation.

Bodies which contain the matter of heat fixed, when put into menſtrua fitted for diſſolving them, generate a degree of heat, greater or leſs, according to the quantity of latent heat ſet at liberty by the more powerful attraction of the menſtruum. Lime, newly burned and put into water, generates a remarkable degree of heat, becauſe a great part of the heat which had been fixed by the calcareous earth is ſet at liberty by means of the water, which is more powerfully attracted by it. That portion of the matter of heat which ſtill remains in ſlaked lime may be diſengaged by an acid; and hence, from an equal quantity of lime a greater degree of heat is generated with acids than with water, as the former ſet the whole of the matter of heat at liberty, the latter only a part. —I have ſpoken briefly, and in a curſory way, of theſe matters, in order to illuſtrate ſeveral things in the foregoing pages, and that what follows may be the better underſtood. We do not here conſider the compoſition of the matter of heat; it is ſufficient for us that it may be fixed, and again ſet at liberty.

Let us now return to the hepatic air, which conſiſts of ſulphur united to the matter of heat by means of phlogiſton. As the demonſtration of this analyſis occurs hereafter, I paſs it over in this place. The hepatic air is decompoſed in the atmoſphere by means of pure air, which attracts phlogiſton ſo greedily, that it is able to ſeparate it from the nitrous acid itſelf: this is the cauſe of the ſulphureous cruſts which are to be ſeen at Aix; for the connecting medium (the phlogiſton) being ſeparated above the ſurface of the water, the whole compound is diſſolved, and the diſengaged particles of ſulphur adhere to the ſurrounding bodies.

Water combines with this hepatic air, and, when impregnated with it, poſſeſſes the genuine properties of hepatiſated waters, as readily appears upon compariſon. But in order to diſcover how much of its virtues depend upon this air alone, and how much upon groſſer materials, we ſhould examine diſtilled water ſaturated with hepatic vapour.—In a moderate heat, a kanne of diſtilled water takes up about ſixty cubic inches of hepatic air, which, when decompoſed by nitrous acid, yield eight grains of ſulphur: the matter of heat which remains diſengaged among the particles of the water, is more and more diminiſhed.

## § IV. *Diſtilled Water ſaturated with hepatic Air.*

In the following ſection we ſhall explain how water may be ſaturated with hepatic air. For the preſent,

ſent, we ſuppoſe the water to be cool, and fully ſaturated.

(A) It has a moſt offenſive hepatic ſmell, when ſet in a broad open veſſel; in 24 hours it blackens ſilver; an effect which, as the vapour is diſſipated in this caſe but ſlowly, it does not produce in leſs than the ſpace of ſome weeks, when ſet to ſtand in an open bottle. This effect may be inſtantly repreſſed by nitrous acid.

The taſte is ſtrong, ſomewhat ſweetiſh, not unlike that of putrid eggs, but more diſagreeable.

It preſerves its clearneſs entirely, if the water be newly diſtilled, ſo as not to have time to abſorb aerial acid from the atmoſphere.

(B) Tincture and paper of turnſole grow but little red, unleſs the water be impregnated with waſhed hepatic air.

Paper of fernambucum ſuffers no change.

(C) No change is occaſioned by acids, unleſs ſuch as poſſeſs the ſingular property of attracting phlogiſton, even in water; one of theſe is the nitrous acid highly concentrated.—When this is dropped in, the ſmell is inſtantly ſuppreſſed, the water grows turbid, and a white ſubtile powder very ſlowly ſubſides: this powder, collected and dried, is found to be pure genuine ſulphur. The phlogiſton being taken away by the acid, the bond of union between the ſulphur and the matter of heat is broken; the hepatic air is therefore decompoſed, and the ſulphur appears in its ordinary form. That the nitrous acid attracts phlogiſton, even in a liquid, is obvious from the artifice made uſe of by ſome to make vitriolic acid, when black, clear again,—they add a ſmall quantity of nitre, which is ſpeedily decompoſed, and the colouring phlogiſton deſtroyed by the diſengaged nitrous acid.

Upon pouring into the impregnated water a few drops of nitrous acid, the fætor is inſtantly ſtopped, but in a few minutes it again returns; and this happens repeatedly; ſo that a quadrant of water requires 200 drops to deſtroy completely all its hepatic air. When the water contains alſo a fixed alkali, the acid has but little effect, ſo long as that is diſengaged; but after it is ſaturated, the hepatic air begins to be decompoſed; the reaſon is clear:—the alkali ſeizes the acid as ſoon as it is dropped in, and repreſſes its activity; hence we eaſily ſee how ſulphur may be precipitated from the Aix waters, which no one, ſo far as I know, has hitherto effected.

Acid of vitriol, and the other common acids, have no effect.

Dephlogiſticated marine acid precipitates the ſulphur.

(D) Alkalis cauſe no change.

(E) Nitrated ſilver occaſions a congrumation, which ſoon changes to a brown colour.—In this caſe the acid and the metallic baſe ſeem to be loaded with phlogiſton, by which they are both rendered inſoluble: there is no doubt but a ſulphur alſo adheres to the metal.—Silver, in its metallic ſtate, grows black in this water.

(F) Nitrated mercury, made without heat, occaſions a brown precipitate; that made with heat, a white one. The difference ſeems to ariſe hence, that in the latter caſe the baſe is ſo far dephlogiſticated, that the phlogiſton remaining is inſufficient for communicating colour to the precipitate.—Mercury, in its metallic ſtate, expoſed to hepatic air, grows black, like ſilver.

(G) Corroſive ſublimate is alſo precipitated white, for the above-mentioned reaſon.

(H) Acetated lead is precipitated black.—Vinegar does not promote the decompoſition of hepatic air: hence, therefore, appears the action of the metallic baſe alone;—yet poliſhed lead, expoſed to hepatic air, does not grow black, but only brown. The ſame is true of iron: copper grows black; but tin, biſmuth, antimony, and zinc, are not changed.

(I) Solution of vitriol of zinc occaſions a little turbidneſs, and yields a white ſediment; that of copper occaſions a yellowiſh brown hue, and ſlowly depoſits a ſediment of the ſame colour; that of iron grows black:—the hepatic ſmell is ſoon diſſipated, if the proportion of the liquors be properly adjuſted.

(K) A grain of white arſenic put into the water grows yellow by degrees, and at length acquires the properties of orpiment. The ſame thing happens to a ſolution of arſenic in water.

(1.) Hepatiſated water, in which filings of iron have been kept for ſome days in a well-cloſed veſſel, grows purple with tincture of galls;—if the iron be diſſolved by an acid, the colour approaches more to violet. This is the reaſon why, with the ſame quantity of tincture of galls, different appearances take place: beſides, we muſt obſerve, that water impregnated with iron by means of hepatic air, is not at all rendered turbid by phlogiſticated alkali; and if a ſmall quantity of vitriol of iron be afterwards added, this produces a ſediment at firſt aſh-coloured, the upper ſurface of which grows by degrees (but very ſlowly) of a pale blue, and after ſome days grows quite black. If hepatiſated martial water grows immediately blue on the addition of phlogiſticated alkali, this is a ſure ſign of the preſence of an acid menſtruum. Theſe circumſtances ſhould be carefully obſerved in the examination of waters.

## § V. *Method of preparing hot medicated Waters.*

In the preparation of hot medicated waters, ſeveral circumſtances are to be attended to:—Firſt, the waters muſt be impregnated with elaſtic fluid; then the groſſer materials, which diſtinguiſh the different ſpecies, are to be diſſolved;

and, finally, the water to be heated without any loſs of its virtue.—We ſhall ſpeak of all theſe in order.

(A) The elaſtic fluid to be employed is either aerial acid or hepatic air, according as the water is required aerated or hepatiſated. The former is obtained by a proceſs already ſufficiently deſcribed; the latter is had in the ſame way, with the difference of a few circumſtances now to be mentioned.

In the place of chalk, we are to employ an hepar ſulphuris, made of equal weights of ſulphur and pot-aſhes together, and melted in a crucible: the hepar is to be reduced to a powder before it is put into the veſſel, as otherwiſe the ſaturating acid will generate upon the ſurface a vitriolated vegetable alkali, which is not ſoluble in a ſmall quantity of water; and this cruſt, ſurrounding the internal parts, will prevent the acid from reaching them.—A maſs made of three parts of iron filings melted, with two of ſulphur, anſwers the ſame end, even better than the former.

An inverted bottle, half-filled with water, is to be ſet to collect the extricated elaſtic fluid: the water cannot take up ſo much of hepatic air as it does of aerial acid;—if the water is to be aerated at the ſame time, $\frac{1}{8}$ or $\frac{1}{4}$ of chalk may be added to the hepar. When, upon agitating the bottle, the hepatic air is no longer diminiſhed, the water is ſaturated.

The vapour being extremely offenſive, and unfriendly to reſpiration, the operator ſhould be ſo ſituated, that a ſtream of air may carry off the noxious vapour from him.

(B) If particular waters are to be imitated, for inſtance, the Caroline or the Aix waters above mentioned, the quantity and quality of their ſeveral contents muſt be determined. The Caroline waters contain, in a kanne,

| | grains. |
|---|---|
| of aerated lime | 24 |
| of vitriolated mineral alkali | 240 |
| of ſea-ſalt | 32 |
| of dried mineral alkali | 68 |

together with an admixture of iron. A kanne of Aix water, taken from the Emperor's bath, contains,

| | grains. |
|---|---|
| of aerated lime, | 27 |
| of ſea ſalt, | 29 |
| of mineral alkali, | 70 |

It is only the aerated lime that indicates the preſence of aerial acid in the Aix waters.

Theſe heterogeneous matters, except the aerated lime (which ought by all means to be left out) are of very eaſy ſolution; they need not therefore be added to the water, until it is to be drank: the proper quantities of theſe may be put into the veſſel out of which the water is to be drank, and are ſoon taken up by the warm fluid.

If any one, however, inſiſts upon the aerated lime, the water muſt firſt be ſaturated with aerial acid, and the lime diſſolved by its means, in the cold, as before deſcribed; the water is then to be impregnated with hepatic air; and in this caſe ſome filings of iron ſhould be added: but if the lime be omitted, the filings put in during the warming of the water will give it a ſufficient impregnation.

(c) In order to make the aerated or hepatiſated water warm, without loſs of virtue, we muſt employ a veſſel cloſely ſhut, ſuch as Papin's digeſter; —the copper ones deſcribed by Mr Wilcke are beſt fitted for this purpoſe: one of thoſe ſhould be taken, which can juſt hold the requiſite quantity of water: the aerated or hepatiſated water being put into this, and well cloſed up, is to be ſuſpended in a common pot in a water-bath; and the water in the greater veſſel, being gradually heated, communicates the requiſite degree of heat to the digeſter.

Although cold aerated water is highly medicinal, as experience evinces; and although the ſame is unqueſtionably true of cold hepatiſated water (§ VI.); yet it is very probable that heat, by increaſing their volatility, renders them more ſubtile and penetrating, and of conſequence more efficacious in certain caſes. We are not yet certain what degree of heat is moſt effectual: the Caroline waters raiſe the Swediſh thermometer to 73°, the Aix waters to 62 ; an heat which appears too great for internal uſe, as the hand can ſcarcely bear water heated to 50°: but this queſtion is not to our preſent purpoſe, it is ſufficient that the water can receive the neceſſary degree of heat, without loſs of virtue.

The ſaline matters ſhould not be put into the digeſter, as many of them act upon the metal, but the iron may ſafely be uſed; and thus it communicates a chalybeate impregnation.

That a glaſs may be occaſionally filled without the loſs of any of the volatile parts, a ſmall ſtopper muſt be fitted to the upper part of the digeſter, by opening which the warm water may be poured out, and yet the maſs remain cloſely ſhut up.

For the purpoſes of bathing, larger quantities are neceſſary; in this intention the Caroline waters (for what reaſon I know not) are out of uſe. The waters of Aix are often employed; and a large quantity of water may be eaſily impregnated with hepatic air, by means of a flexible tube conveying the air to the bottom; and this operation may without inconvenience be continued, even while the patient ſits in the bath; but the proceſs ſhould be ſo conducted as to affect reſpiration as little as may be.

§ VI.

## § VI. *Appendix, concerning cold hepatiſated Waters.*

Cold martial waters, when freſh, almoſt always have an hepatic ſmell, eſpecially when a little ſhaken in a cloſed bottle, yet in general the impregnation is ſo ſlight that it goes off in a few moments; but I have lately learned that the hepatic impregnation, in ſome inſtances, is more complete. Mr Alſtroemerer ſent me 12 kannes of Medway water, requeſting me to examine their contents. Theſe acidulous waters are ſituated at Medway, in Oſtro Gothland, and have been celebrated for wonderful cures, from the moſt remote periods of time: the celebrated U. Hierne diſcovered them in the year 1677, from which time they have been much frequented every year, and with conſiderable advantage; yet their true nature and properties are but little known.—The following experiments will tend to throw light upon this ſubject.

This water, when brought to Upſal, is found to have loſt its volatile principles, but Dr P. Dubb examined it at the very fountain, by the means above deſcribed:—he obtained from every kanne 13 cubic inches of an elaſtic fluid, which diſtinctly reddened tincture of turnſole, and therefore undoubtedly was aerial acid. That it alſo contains ſome hepatic air, will clearly appear from what follows; but theſe 13 cubic inches, having been collected by means of water, do not indicate the true quantity; and I doubt not but that, if they had been collected by mercury, they would amount to 30 at leaſt.

In the Medway water there cannot be any pure air, as that is inconſiſtent with a martial ſolution; but the hepatic air remained in the reſiduum of 10⅓ kannes, reduced by evaporation, at the very fount, to nearly 2 quadrants: this appears manifeſtly, for the bottle in which the liquid reſiduum was put, when opened, ſtruck the noſe with an offenſive hepatic odour; and a portion of this liquor, upon the addition of a few drops of concentrated nitrous acid, grew white and turbid, and in 24 hours depoſited a very ſubtile ſulphureous powder:—in this caſe then, we have a cold hepatiſated water, which retains that fetid principle ſo tenaciouſly, that notwithſtanding continued boiling, and the agitation of a long journey, it yet retained a conſiderable portion of the volatile aura.

In order to diſcover the fixed principles, I firſt employed precipitants; but I muſt obſerve, that the water ſent to me was ſomewhat yellow, very faintly indeed, yet ſenſibly ſo, eſpecially when compared with common water: in the liquid reſiduum, that colour was more conſpicuous, and the reſiduum itſelf nearly turbid.

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In taſte and ſmell it reſembled pure water, but the liquid reſiduum gave ſlight tokens of iron and of an hepar.

Papers tinged with turnſole or Brazil wood diſcovered nothing; hence it would appear that there is no prevalence either of acid or alkali.

Phlogiſticated alkali cauſed no change either in the water or in the liquid reſiduum; and this was the caſe at the very fountain (§ IV. L).

Tincture of galls alſo had no effect on the water, but with the reſiduum formed a dilute purple colour; which yet was ſomewhat changed by the yellowiſh brown of the water itſelf.

Acid of ſugar did not occaſion a turbidneſs in the water, until after the ſpace of 24 hours; but with the reſiduum immediately formed a ſaccharated lime.

Aerated fixed alkali does not make the water turbid, but it inſtantly acts upon the reſiduum; the precipitate was white, and of a calcareous nature.

Salited terra ponderoſa did not precipitate any thing, even in the reſiduum; there is of courſe no vitriolic acid preſent.

A ſmall piece of alum was decompoſed after ſome hours, which is no doubt occaſioned by a ſalited lime, mixed with the alum.—Hepatic air does not act at all upon ſolution of pure alum.

A ſolution of nitrated ſilver renders the water ſomewhat turbid; but in the reſiduum it occaſions a complete milkineſs, tinged lightly brown by the hepatic air;—there is preſent, therefore, a marine acid.

Nitrated mercury, prepared without heat, as alſo acetated lead, exhibit the very ſame appearances as nitrated ſilver.

Corroſive ſublimate has no effect.

Theſe experiments detect nothing but a ſmall portion of ſalited lime, except the admixture of iron, which the tincture of galls ſhews.

I evaporated half a quadrant of the liquid reſiduum to dryneſs, but found only 5 grains of a brown powder, which grew a little moiſt in the air, yet only a grain or two of it was ſoluble in water; ſo that the greateſt part of this was a calcined iron. Water poured upon the dry reſiduum grows brown, an appearance occaſioned by a mucilaginous extract; for, evaporating again to dryneſs, it exhibits a brown matter, which grows white by burning. Since, then, 10¼ kannes yielded two quadrants of this liquid reſiduum, it appears, that we ſhould allow about two grains to each kanne; for the ſalited lime amounts ſcarcely to half a grain: I have alſo obſerved a few particles of ſea-ſalt.

The dry reſiduum which, according to Dr Dubb's experiments, is obtained from each kanne by boiling for an hour, weighs 2,75 grains, which ſeems to be purely martial; and it is to be

obſerved

BIBLIOTHECA·BODLEIANA

# SYNO

## The SUBSTANCES containe A

## ENGLISH WEIGH

hes.

| NAMES of the WATERS. | | | | Physical Qualities. Temperature. | Weight. | Specific Gravity. | lited gnefia | S Mi |
|---|---|---|---|---|---|---|---|---|
| Diſtilled Water, — — | | | | — | Grains. 8923.8961 | 1.0000 | — | |
| Snow Water, — — — | | | | — | 8924.7884 | 1.0001 | — | |
| Sea Water, at the Depth of 60 Fathom, | | | | — | 9193.7956 | 1.0289 | 7640 | 303 |
| Mineral Waters. | Cold. | Aerated. | Seydſchutz, — | — | 8977.4393 | 1.0060 | 3714 | |
| | | | Seltzer, — — | — | 8948.9905 | 1.0027 | — | 13 |
| | | | Spa, — — | — | 8932.8199 | 1.0010 | — | 0. |
| | | | Pyrmont, — | — | 8950.1335 | 1.0024 | — | 1. |
| | | Aerated and Hepatic. | Medway, — | — | — | — | — | |
| | Hot. | Hepatic. | Aix la Chapelle, | 142° | — | — | — | 6. |
| | | | Caroline, — | 164° | — | — | | |

rved, that part of it is magnetical;—this pro-
y is, beyond doubt, communicated by the he-
c air.

Ve conclude, therefore, that a kanne of freſh
lway water contains.

| | grains. |
|---|---|
| f iron, partly diſſolved in hepatic air, and partly in aerial acid, - | $4\frac{1}{4}$ |
| f ſalited lime, - - - | $\frac{1}{2}$ |
| | $4\frac{3}{4}$ |

| | cubic inches. |
|---|---|
| f aerial acid, nearly - | 30 |
| f hepatic air, at leaſt - | 40 |

The ſea-ſalt and mucilaginous extract, are of
ittle weight, that they may in this computation
neglected.

This water muſt neceſſarily be very efficacious:
1ſt, it contains united two principles, one of
ch gives virtue to the hot, the other to the
l medicated waters: 2d, it contains nothing
ious.—We know that many waters, even the
much celebrated Pyrmont, are loaded with
ted lime and gypſum, ſubſtances which are
o means friendly to the human ſyſtem; and
experience of a whole century abundantly
confirms

confirms this opinion of the virtue of the Medway waters, which we have deduced from analyſis.

How this water may be imitated, is eaſily ſeen from what has been already ſaid.

# DISSERTATION VIII.

## OF THE

## ACID OF SUGAR.

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### § 1. *Method of obtaining the Acid of Sugar in a ſeparate State.*

SUGAR being juſtly conſidered as an eſſential ſalt, it will readily be granted, that it contains an acid;—this acid may be ſeparated, and exhibited in a cryſtalline form, by the following proceſs:—

(A) Let one ounce of the pureſt ſugar, in powder, be mixed, in a tubulated retort, with three ounces of ſtrong nitrous acid, whoſe ſpecific gravity is nearly 1, 567.

(B) When the ſolution is completed, and the moſt phlogiſticated part of the nitrous acid has lown off, let a receiver be luted on, and the ſolution gently boiled;—in this proceſs an immenſe quantity of nitrous air is diſcharged (*a*).

(C) When the liquor acquires a dark brown colour, let three ounces more of nitrous acid be poured on, and the boiling continued until the coloured and ſmoking acid has entirely diſappeared.

(D) Let the liquor in the receiver be then poured into a larger veſſel; and, upon cooling, ſmall quadrilateral priſmatic cryſtals are found adhering together at an angle generally of about 45°: theſe, collected and dried on bibulous paper, weigh 109 grains.

(E) The remaining lixivium, boiled again in the ſame retorts with two ounces of nitrous acid until the red vapours begin to diſappear, upon cooling, as before, affords 43 grains of ſaline aciculæ.

(F) If to the viſcid glutinous liquor which remains, there be added, at different times, ſmall quantities of nitrous acid, amounting in all to two ounces; by boiling, and evaporating to dryneſs, a ſaline maſs is at length formed, brown, glutinous, and deliqueſcent, which, when perfect-

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(*a*) In order to procure this acid, common aqua fortis will ſerve juſt as well as the ſtrongeſt nitrous acid; and any glaſs, thin enough to bear a moderate heat, will do juſt as well as a retort. Nothing can be more eaſy than the proceſs for obtaining the acid of ſugar. B.

ly dried, weighs half a drachm; but in depuration nearly half of this weight is loſt.

(G) The cryſtals obtained in the manner above deſcribed, are to be depurated by repeated ſolution and cryſtallization, an operation which is particularly neceſſary to the portion got, as deſcribed in F. The laſt lixivium F, digeſted with nitrous acid, and evaporated to dryneſs by the ſun's heat, exhibits priſms ſimilar to thoſe mentioned in D and E; ſo that this affords a method of abridging the number of depurations.

(H) To obtain, therefore, one part of this ſalt, there are required 3 of ſugar, and 30 of nitrous acid; ſo that it may be reckoned among the moſt expenſive ſalts hitherto known. It muſt be particularly obſerved, that a much ſmaller quantity of cryſtals will be obtained, if the boiling be continued ever ſo little beyond the proper time.

(I) The acid thus obtained I call *acid of ſugar*; not becauſe it is procurable from that ſubſtance only, but becauſe ſugar affords it more pure, and in greater quantity, than any other matter hitherto tried. Thus 100 parts of gum arabic, treated as above, with 900 of nitrous acid, at the beginning of the boiling foam violently, and upon cooling, yield ſcarce more than 21 of ſaccharine acid, priſmatically cryſtallized; but at the ſame time the ſolution, even to the laſt, ſeparates a ſaccharated lime (§ VI), which, when collected, weighs 11, and contains about 5 of the acid of ſugar: 8 parts of highly rectified ſpirit of wine, with 24 of nitrous acid, yield 3 of ſaccharine acid, but for the moſt part in a ſquamous form, and loaded with much moiſture; beſides, honey, and whatever ſubſtance contains ſugar, in the ſame way produces the ſame acid; and although acid of tartar, diſſolved and boiled in nitrous acid, in the ſame manner, yields a ſalt ſomewhat ſimilar to this, both in taſte and ſquamous cryſtallization, yet it is of a whiter colour; and, beſides, is unchangeable in the fire, yielding only a coal as before.

In another Diſſertation it will be ſhewn, that the acid of ſugar occurs alſo in the animal kingdom; and that it, together with a gluten, conſtitutes the calculi of the kidnies and bladder (*b*).

## § 11. *Properties which the Acid of Sugar poſſeſſes in common with other Acids.*

This ſalt poſſeſſes many properties, ſome peculiar to itſelf, ſome common to it with the other acids,

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(*b*) This has not yet been made to appear; and it is certain that this acid, if it be preſent at all, is not the only one contained in calculi, for phoſphorus has been obtained from them by diſtillation with inflammable ſubſtances. The acid of ſugar is preſent in a vaſt variety of different animal and vegetable ſubſtances; it exiſts in great quantities in gall-nuts and wool; at leaſt it is obtained from them, when treated with nitrous acid. Mr Morveau conjectures plauſibly, that it has for its baſis a ſubtile oil.

acids, though differing more or leſs in degree: and theſe we are now to conſider.

(A) The cryſtals have an exceeding pungent taſte;—but a ſolution of theſe, when ſufficiently diluted, excites a very agreeable ſenſation on the tongue. Twenty grains communicate a ſenſible acidity to a kanne of water.

(B) It makes red all the blue vegetable juices, except that of indigo A ſingle grain, diſſolved in four ounces of water, inſtantly makes red the blue paper uſed for covering ſugar-loaves, which is not affected by the weaker acids; and 12 grains, diſſolved in a kanne of water, produce the ſame effect upon paper tinged with turnſole.

(C) It attacks alkalis, earths, and ſundry metals, and diſſolves them with effervеſcence, if they be united with aerial acid. Theſe combinations, which ſerve to diſtinguiſh this evidently from all other acids, will be deſcribed in § III.—XXIV.

(D) Diſtilled water, when boiling, diſſolves its own weight of the cryſtals. In an heat of 15°, it diſſolves only half that quantity; and, although the ſolution appears at firſt a little turbid, it ſoon recovers a perfect tranſparency: the ſpecific gravity of this laſt ſolution, when ſaturated, is 1,0593. The vapours which break forth during the boiling of the former ſolution do not contain any acid; and the liquor, as it grows gradually cold, depoſits a great quantity of cryſtals, many of which exhibit priſms diverging from a point.

Each of theſe has four ſides obliquely ſituated, as in the ſpar; the alternate ſides narrower, of which two quadrilateral planes, generally unequal, meet together like a roof, conſtituting an apex at one or both extremities. Sometimes the priſms occur ſo ſhort as entirely to reſemble the ſpathaceous cubes, with acute angles, truncated in a parallel direction; ſo that hence we may eaſily judge of their primitive form.

Sometimes the priſm is rectangular, and the planes of the apex equal: the figure of the apex too is varied by planes riſing from the angles of the priſms. If, during the depoſition, the veſſel be ſtirred, or if the quantity of diſſolved matter be inſufficient, the priſms become irregular, and truncated, with five or ſix ſides.

(E) Theſe cryſtals do not refuſe to unite with other acids. Concentrated vitriolic acid, ſeizing the oily matter, grows brown; and, in the end, totally conſumes the cryſtals, eſpecially on boiling; but when diluted, although it diſſolves the cryſtals readily, yet it yields them up again, but in the form of aciculæ; a change which this acid is wont to induce alſo upon other ſalts. The nitrous acid greedily takes up the acid of ſugar, and, upon boiling, grows yellow; upon cooling, it again ſeparates cryſtals, but they are generally irregular. If the ſolution be often repeated, with the aſſiſtance of heat, the ſaccharine acid is totally deſtroyed; and at length no cryſtals appear.

The marine acid and vinegar diſſolve theſe cryſtals very completely, but they yield them again totally unchanged both as to their ſhape and nature.

(F) 100 parts of ſpirit of wine, on boiling, take up nearly 56 of this acid; but in a moderate heat not above 40. This ſolution grows a little turbid, and depoſits a mucous ſediment, ſcarcely equal to $\frac{1}{10}$ of the acid; on cooling, ſquamous cryſtals are formed; theſe are irregular, have a fragrant ſmell, and, on drying, grow white. In order to determine the effect of this acid in forming an ether, two drachms of the cryſtals, diſſolved in as much ſpirit of wine, (of the ſpecific gravity 0, 8581) were boiled over a ſlow fire in a ſmall retort; as ſoon as oily ſtriæ began to ariſe another receiver was luted on, and half a drachm, which was contained in the former receiver, was found to be nothing but the ſpirit deprived of its ſuperfluous phlegm; that which came over along with the ſtriæ, weighed only a few grains more than the former liquor, this was an acid, and, upon evaporation, yielded a cryſtallized ſaccharine acid; upon the addition of lime water, a ſaccharated lime fell to the bottom, and on the top there floated a thin ſtratum of ether, holding, in a blue ſolution, a calx of copper and of gold (the laſt, probably, alloyed with copper). This liquor, if it may be properly called an ether, differs much from the common ether; for it is not inflammable, except when hot; nor does it burn with a white, but with a blue flame, only white on the ſurface; and, finally, the fragrancy of its ſmell is but weak; perhaps if the experiment was made with a larger quantity, it would ſucceed better: after the ſtriæ had ceaſed, there came over a drachm of an acid liquor, which precipitated lime-water, and on evaporation yielded a cryſtalline acid of ſugar; there came over, alſo, about half a drachm of an heavier oil: the reſiduum conſiſted of cryſtallized ſaccharine acid, and weighed 29 grains; this réſiduum, which had but little empyreuma, again treated the ſame way with two drachms of ſpirit of wine, yielded a few oily ſtriæ, and a ſmall quantity of oil: the black reſiduum, which weighed near 12 grains, exhibited brown cryſtals; and in the fire ſent forth a white and pungent ſmoke.

(G) Vitriolic ether diſſolves the cryſtallized acid of ſugar, but with difficulty.

(H) The ſaccharine acid unites with the oils both eſſential and expreſſed, but ſeparates again on proper evaporation: in a more violent heat, alſo, it ſeparates, by riſing above the ſurface.

(I) In an heat exceeding 15°, the cryſtals are gradually covered with a white opake cruſt; and at length, entirely ſplitting into a white powder, loſe about $\frac{3}{10}$ of their weight; which loſs is quickly recovered in a moiſt air: the cryſtals, when old, are covered with a looſe down, ſuch as appears upon lutes during diſtillation; but is in no reſpect different from the ſaccharine acid itſelf.

In low cloſe diſtilling veſſels, with a gentle fire, the water of the cryſtals firſt comes over (which forms about $\frac{3}{10}$ of the whole) and the acid is fuſed. When the heat is intenſe, it ſoon liquefies, and upon boiling grows brown; a little phlegm comes over into the receiver, an acid powder efforeſces upon the luting of the receiver, and a white ſaline cruſt ſublimes, nay, when the fire is vehement, ſome of it is forced over into the receiver; but the greater part is deſtroyed, leaving in the retort a brown or grey matter, equal to nearly $\frac{1}{50}$ of the cryſtals; this has an empyreumatic ſmell, makes concentrated vitriolic acid brown, and nitrous acid yellow, but is diſſolved in marine acid, without inducing any change of colour. This reſiduum, expoſed to the fire in an open veſſel, flies off, leaving nothing in the glaſs but a white ſpot. The acid of ſugar, when ſublimed, eaſily puts on a cryſtalline form, and ſeems to have undergone no change, except that it is rendered extremely pure, being deprived of ſo much of its oil as it can loſe without being itſelf deſtroyed. In the receiver is found an acid liquor, which precipitates lime-water, and alſo exhibits the properties of ſaccharine acid, but does not eaſily cryſtallize: a prodigious quantity of elaſtic vapour is generated, which, upon ſeparating the veſſels, is found to be of an highly pungent and empyreumatic ſmell;— this vapour, collected during diſtillation, amounts to nearly 100 cubic inches in every half ounce of the cryſtals, and conſiſts one half of aerial acid, which may eaſily be ſeparated by lime-water, the other half is inflammable air, and burns with a blue flame (*b*).

Acid of ſugar which has been once ſublimed, when again ſubjected to the ſame operation, ſends forth a white ſmoke; this, collected in a receiver, exhibits, upon cooling, an acid liquor, of a water-green colour, which is not cryſtallizable: on the ſides and neck of the retort, alſo, ſome of the acid is found ſublimed, and ſcarcely changed; the reſiduum is grey.

Upon ſubliming a third time, the receiver was burſt by the elaſtic vapour: nevertheleſs a minute portion of an acid liquor was collected, which, upon evaporating to dryneſs, left a ſmall reſiduum: the reſiduum in the retort was hoary. The changes now deſcribed are brought about more ſpeedily by means of heat in open veſſels: the ſmoke ariſing is offenſive to the noſtrils and the lungs, and the reſiduum is of a whiter colour; in this caſe there occur no veſtiges of a coal, a circumſtance

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(*b*) M. Morveau obſerves, that the Abbé Fontana's analyſis of this acid is conſiderably different. He does not eſtimate the aerial acid at above a third: and the inflammable air ſeemed to him to be mixed with common air. He affirms, that an ounce of the cryſtals yielded 432 cubic inches of theſe elaſtic fluids, a quantity nearly double to that aſſigned by Profeſſor Bergman. M. Morveau attributes this difference to the different means which he ſuppoſes theſe two illuſtrious philoſophers employed to convert the acid into elaſtic fluid. B.

circumſtance which clearly diſtinguiſhes the acid of tartar from that of ſugar.

### § 111. *Saccharated vegetable Alkali.*

The acid of ſugar, exactly ſaturated with vegetable alkali, does not yield cryſtals without difficulty—but if either the acid or the alkali be a little predominant, cryſtals are eaſily obtained: two parts of alkali, fully aerated, combined with one of ſaccharine acid, being ſkilfully evaporated, afford beautiful priſms, nearly of the ſame form with thoſe of the acid itſelf: theſe cryſtals heighten the blue colour of paper tinged with turnſole; but if boiled in the tincture of turnſole, or in ſyrup of violets, they change the colour to a red: they diſſolve eaſily in water; but with difficulty in ſpirit of wine; they undergo ſpontaneous calcination in heat: the ſaccharine acid is ſeparated from the cryſtals by lime, terra ponderoſa, or magneſia, when pure; the acids of vitriol, of nitre, of ſalt, of fluor, of arſenic, and of phoſphorus, alſo induce a change, by attracting the alkaline baſe.—Acetated and formicated vegetable alkali are decompoſed by acid of ſugar: but it is fire alone that can perfectly expel the ſaccharine acid from any baſe. In diſcovering lime in any manner, lodged in waters, the ſaccharated vegetable alkali is preferable to any ſubſtance hitherto known, as it attracts lime moſt powerfully, and is able to diſengage it from any other acid: it forms, with the lime, a ſalt, very difficult of ſolution, which therefore falls to the bottom in the form of a white powder (§ VI.). Although this effect may be produced by the acid alone, yet the double (*c*) affinity accelerates the operation, at leaſt never impedes it.

## § IV. *Saccharated mineral Alkali.*

Two parts of newly cryſtallized mineral alkali, combined with one of ſaccharine acid, form a ſalt very difficult of ſolution, which is partly ſeparated during the operation, but what remains after evaporation yields cryſtalline grains: theſe cryſtals diſſolve perfectly in warm water, but not in ſpirit of wine; they do not change the tincture of turnſole, but make ſyrup of violets green: the ſame earths, and the ſame acids, decompoſe this and the former ſalt; and, beſides, the mineral alkali is expelled by the vegetable.

## § V. *Saccharated volatile Alkali.*

One part of ſaccharine acid takes up ſix of pure volatile alkali (diſtilled from one of ſal ammoniac, four of quick lime, and three of water). This combination being ſlowly evaporated, yields quadrangular

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(*c*) See Treatiſe on Elective Attractions.

drangular priſms, generally diverging from a number of points. Theſe cryſtals not only redden tincture of turnſole, but alſo ſyrup of violets; they ſplit in heat, loſing about $\frac{1}{6}$ of their weight: this loſs takes place in the ſaccharated volatile alkali more ſlowly than in the acid of ſugar itſelf: water readily diſſolves theſe cryſtals; ſpirit of wine does not: upon diſtillation, they yield firſt a concrete volatile alkali, then ſomewhat of a ſaccharated volatile alkali.—The coally reſiduum indicates a decompoſition, and conſequently the diſengagement of aerial acid, and the cauſe of the concretion of the volatile alkali;—this union is decompoſed by fixed alkalis, and by the earths and acids which decompoſe the former, (§ III. and IV.).

## § VI. *Saccharated Lime.*

82 parts of ſaccharine acid take up 100 of pellucid calcareous ſpar, but not immediately, becauſe the ſurface, when ſaturated with the acid, prevents the acceſs of the acid to the internal nucleus. Nitrated lime is completely precipitated by acid of ſugar in the form of a white powder, not ſoluble in water; of 119 parts by weight of this powder, 72 fall to the bottom, and 47 appear upon evaporation: hence it appears, that 100 parts contain, of acid 48, of pure lime 46, and of water 6; ſo that not only the preſence of lime

in water is diſcovered by acid of ſugar, but even its quantity may, without difficulty, be aſcertained.

The ſaccharine acid attracts lime with ſuch force, that it ſeparates it from every other: this combination, therefore, cannot be decompoſed by any acid, alkali, or earth, hitherto known, and can only be decompoſed by fire (*e*).

Hence alſo we underſtand the neceſſity of lime-water in the purification of ſugar. For the juice of the cane contains a ſuperabundance of acid, which prevents the dry concretion; and even if to pure ſugar diſſolved in water be added the ſaccharine acid, it will not form cryſtalline grains. Now, nothing more powerfully attracts this acid than lime; and when united with it, it is inſoluble, and either falls to the bottom, or floats in the ſcum: lime-water, therefore, affords the moſt complete means of effecting the cryſtallization, as it removes the impediment, and, beſides, may eaſily be added in any proportion, without communicating

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(*e*) This teſt, however, is not ſo perfect as terra ponderoſa for detecting vitriolic acid. Bergman himſelf (Obſ. on Calculus) has pointed out one caſe in which it fails; and there are certainly others in which it acts more ſlowly than could be wiſhed, as on ſtrong ſolutions of lime in acids; and others, again, in which its action is prevented by cauſes that have not accurately been aſſigned. I have frequently found it capricious; for ſo my ignorance obliges me to expreſs myſelf.

any heterogeneous matter. Many perſons have thought that a portion of the lime remains mixed with the ſugar; but if the purification be properly conducted, the nature of the ingredients, the circumſtances of the operation, and, finally, the moſt accurate analyſis, abundantly ſhew, that there is not the ſmalleſt trace of lime remaining:—good ſugar diſſolves totally in diſtilled water; which could not poſſibly be the caſe if there was preſent any lime, either crude or united with the ſaccharine acid, as either of theſe ſubſtances, whether alone or mixed with ſugar, is utterly inſoluble in water. The vegetable alkali does indeed abſorb the acid of ſugar, but forms with it a ſalt not very difficult of ſolution, (§ III.); and, beſides, a cauſtic lixivium, if uſed in too great quantity, will diſſolve a portion of the ſugar. In ſaccharated lime, the earthy baſis predominates; for, when boiled with ſyrup of violets, it ſtrikes a green colour (*f*).

§ VII.

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(*f*) "Phyſicians are ſometimes heard to ſay, that the uſe of ſugar may be hurtful, on account of the lime uſed in refining it. But ſuch muſt belong to the claſs, unhappily too numerous, whom intereſt prompts to contend, that chymiſtry is of no ſervice in the practice of medicine.

"We have here alſo a ſtriking proof of the influence of chymiſtry in the improvement of the arts. The author's diſcovery cannot fail to illuſtrate the proceſs for refining ſugars: it had been ſuſpected that the lime attracted ſome unctuous ſubſtance, or an acid. But this was mere conjecture;

## § VII. *Saccharated Terra Ponderoſa.*

Acid of ſugar, ſaturated with terra ponderoſa, quickly depoſits pellucid angular cryſtals, ſcarcely ſoluble in water; boiled in diſtilled water, they ſplit, and yield an opaque powder; but on cooling, the ſmall portion which is diſſolved again concretes into cryſtals, containing a ſuperabundant acid; for this combination never cryſtallizes, unleſs the acid be predominant. Now, the hot water takes the ſuperabundant acid from the greateſt part, and therefore renders it inſoluble, no more acid remaining than what is neceſſary to ſaturation;—they ſcarcely diſſolve in ſpirit of wine;—they yield their menſtruum to lime. Saccharated terra ponderoſa, put into a lixivium of pure vegetable alkali, is covered with an opaque cruſt, and at length falls into a powder: the alkali is found united with the ſuperabundant acid.

jecture; and it will be eaſy (now the object to be accompliſhed, and the manner of action of the matters employed, are known) to improve the mode of proceeding. The lime, I ſhould ſuppoſe, ſerves to ſeparate not only the ſuperabundant acid furniſhed from the cane, but that alſo which is developed by the action of fire, or by an incipient ſpontaneous fermentation of the eſſential ſalt: for, independently of the loſs in coarſe ſugars, that which has been long kept in a damp place has been obſerved to turn yellow and viſcid (*gras*); inſomuch that it became neceſſary to refine it again."—Morveau.

§ VIII.

### § VIII. *Saccharated Magneſia.*

The acid of ſugar diſſolves magneſia, and forms a middle ſalt, in the form of a white powder, which is not ſoluble either in water or ſpirit of wine, unleſs the acid be ſuperabundant. 100 parts of this ſalt contain 35 of pure magneſia, and of acid and water about 65: the fluor acid is the only one which decompoſes this ſalt; it is alſo decompoſed by lime and terra ponderoſa: pure magneſia ſeparates the ſaccharine acid from alkaline ſalts.

### § IX. *Saccharated Clay.*

42 parts of earth of alum, well waſhed, are diſſolved by digeſtion in 53 of acid of ſugar. This ſolution, on evaporation, does not produce cryſtals, but a yellowiſh pellucid maſs, of a ſweet yet aſtringent taſte. This, when dry, deliquiates in a moiſt air, and gains $\frac{2}{7}$ of its weight: it reddens tincture of turnſole, but not ſyrup of violets; it diſſolves ſparingly in ſpirit of wine; in the fire it ſwells, the acid flies off, and leaves behind a brown earth.—100 parts contain about 44 of earth, and 56 of acid and water. The vitriolic, nitrous, and marine acids, the alkaline ſalts, terra ponderoſa, lime, and magneſia, all decompoſe ſaccharated clay. Iron alſo is attacked by a ſolution of this ſalt; and

the iron ſeparates, united with the ſaccharine acid, (§ XVI.).

Alum is not decompoſed by acid of ſugar; neither does nitrated or ſalited clay yield their baſe to it.

## § X. *Saccharated Gold.*

The acid of ſugar does not act upon gold while in ſolution; yet if it be precipitated by a fixed alkali, and well waſhed, this acid blackens, but ſcarcely diſſolves it.

## § XI. *Saccharated Platina.*

Platina is not diſſolved, unleſs precipitated by an alkali. Now, the vegetable alkali partly unites with the diſſolved platina, forming a ſalt very difficult of ſolution; which therefore, upon the addition of the alkali, falls to the bottom like a precipitate, although in reality it contains aqua regia, or at leaſt marine acid; therefore, to avoid confuſion, I make uſe of platina precipitated by a mineral alkali, and well waſhed. I know ſome expert chymiſts aſſert, that this noble metal does not yield to mineral alkali; but the contrary is eaſily ſhewn.—Of this we have treated elſewhere at large; therefore we return to the ſolution made by acid of ſugar: this is yellow, and yields yellow cryſtals.

### § XII. *Saccharated Silver.*

Acid of ſugar diſſolves ſilver precipitated by a fixed alkali but ſparingly, and does not attack the metal itſelf. This combination is moſt conveniently obtained from a ſaturated ſolution of ſilver in nitrous acid. The ſilver, upon the addition of acid of ſugar, precipitates in the form of a white powder, which, when waſhed, does not change even the tincture of turnſole; ſcarcely diſſolves in water, much leſs in ſpirit of wine; yet is ſoluble in nitrous acid, and grows black by the rays of the ſun. Acid of ſugar alſo decompoſes vitriol of ſilver, but not ſalited ſilver, ſo far as I have hitherto been able to determine with certainty.

### § XIII. *Saccharated Mercury.*

Mercury, like the former metals, is not acted upon by acid of ſugar, unleſs it be partly deprived of its phlogiſton; but in that ſtate it is diſſolved, forming a powdery white ſalt, which is not ſoluble in water, unleſs the acid predominates, and grows black when expoſed to the ſun. The ſame ſalt may be had from mercury diſſolved in nitrous or marine acid, by the addition of acid of ſugar, which immediately occaſions a precipitation. Corroſive ſublimate, by this method, yields a fine powder, but ſlowly, and in very ſmall quantity, which does not grow black in the light.

## § XIV. *Saccharated Lead.*

Lead, digeſted with acid of ſugar, is corroded, but ſcarcely diſſolved, unleſs it be calcined, eſpecially by precipitation with an alkali. This ſolution, when approaching to ſaturation, is made turbid by ſaline grains, which ſeparate and fall to the bottom. The ſame happens upon adding acid of ſugar to ſolution of lead, in nitrous acid, marine acid, or vinegar: theſe cryſtals contain about 55 parts of lead in 100; they do not diſſolve in ſpirit of wine, and ſcarcely in water, unleſs it be ſharpened by an acid. A ſolution of vitriolated lead is not precipitated by the ſaccharine acid.

## § XV. *Saccharated Copper.*

Acid of ſugar attacks copper, even in its metallic ſtate; but with greater eaſe if it has been diſſolved and precipitated by an alkali. Both ſolutions form a powder of a dilute blue colour, which, unleſs the acid predominates, is ſcarcely ſoluble in water: 21 parts of copper require 29 of acid. Copper is precipitated by ſaccharine acid, from its ſolution in vitriolic, nitrous, or marine acid. The colour of a ſolution of this ſalt is

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a mixture of blue and green, the copper depoſits upon zinc or iron. The acid of ſugar decompoſes acetated copper ſo completely, that the concentrated vinegar may be ſeparately collected, only a little adulterated with copper.

## § XVI. *Saccharated Iron.*

The acid of ſugar attacks iron with an effervescence, which is occaſioned by the extrication of phlogiſton (*g*). The ſolution has an aſtringent ſweetneſs; and, when made without heat, exhibits priſmatic cryſtals of a greeniſh yellow colour, eaſily ſoluble in water, poſſeſſing a ſuperabundance of acid, and yet ſplitting in heat. In 100 parts there are 55 of acid, and 45 of iron. The acid being expelled by fire, there remains a ferruginous maſs marked with greeniſh ſqua-

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(*g*) "I do not believe that the ſeparation alone of phlogiſton can occaſion a ſenſible efferveſcence. This phænomenon takes place in the ſolution of metals, in proportion to the decompoſition of the acid, at leaſt a partial decompoſition; whence an elaſtic fluid is produced, which unites with phlogiſton, and becomes inflammable air." Morveau. — Mr Kirwan would explain this appearance by ſaying, that the acid, in diſſolving the metal, gives out fire to the phlogiſton, which enables it to aſſume an aerial form; and if it ſhould at laſt be proved, that inflammable air is one of the ſtates of phlogiſton, this muſt be accepted as the true theory. B.

mulæ on the ſurface, but the nucleus verges to a brown.

Calx of iron is alſo diſſolved; but on digeſting both it and the foregoing ſolution, they yield nothing but a yellow powder, ſuch as is precipitated from green vitriol by acid of ſugar, and is alſo had in the preparation of the ſaccharine acid, when the nitrous acid employed abounds with iron. This powder is almoſt inſoluble in water, but on boiling ſeparates an ochre.

## § XVII. *Saccharated Tin.*

Tin, by the aſſiſtance of heat, is blackened by the acid of ſugar, and at length covered by an hoary powder: the ſolution emits elaſtic vapours, poſſeſſes an auſtere taſte, and exhibits priſmatic cryſtals; but when quickly evaporated to dryneſs, nothing remains but a corneous maſs, which being diſſolved, on the addition of an alkali yields a copious precipitate. The calx of tin is alſo eaſily diſſolved, and both the combinations make tincture of turnſole red.

## § XVIII. *Saccharated Biſmuth.*

The regulus of biſmuth is ſomewhat corroded by acid of ſugar; but the calx only is diſſolved.— This ſalt is powdery and white, and ſcarce ſoluble in water; the metal conſtitutes one half of its weight.

If to a ſolution of nitrated biſmuth be added the ſaccharine acid, in the ſpace of an hour polygonal tranſparent grains concrete at the bottom of the veſſel, which have the ſame properties as the above-mentioned powder, nor do they occaſion opacity in water, like the cryſtals of nitrated biſmuth.

## § XIX. *Saccharated Nickel.*

The regulus of nickel, digeſted in acid of ſugar, is covered with a greeniſh white cruſt, and at length all ſplits into a powder of the ſame colour; the green calx alſo aſſumes the ſame colour, even without heat.—This combination contains twice as much acid as metal. The ſaccharine acid precipitates a powder of the ſame kind from nickel diſſolved in vitriolic, nitrous, or marine acids: this ſalt, is diſſolved in water in ſmall quantity, and aſſumes a yellow colour, ſcarce tinged with green; and the cryſtals are of the ſame colour.

## § XX. *Saccharated Arſenic.*

Arſenic in a reguline ſtate is ſcarcely diſſolved by digeſtion, but white arſenic is eaſily taken up without heat; on evaporation it exhibits priſmatic cryſtals, which, melting with a gentle heat, emit the ſuperabundant acid, and ſhoot into elegant ramifications; theſe eaſily diſſolve in water, and in ſpirit of wine make tincture of turnſole red; are ſublimed by a gentle fire, but deſtroyed by a ſtronger; the ſaccharine acid firſt flying off, and then the white arſenic, with a ſmell of garlick.

## § XXI. *Saccharated Cobalt.*

Acid of ſugar attacks cobalt, either with or without heat, and converts it into a powder of a dilute roſe-colour. The ſolution is more yellow, and exhibits cryſtals of the like colour, abounding in acid, and therefore eaſily ſoluble; but the roſe-coloured powder, which does not change turnſole, is ſcarcely ſoluble in water. The acid of ſugar, in a moderate heat, takes up more than an equal weight of precipitated cobalt: on the addition of common ſalt this ſolution yields a ſympathetic ink.

The ſaccharine acid ſeparates cobalt from all acids yet known, and forms the above-mentioned powder.

## § XXII. *Saccharated Zinc.*

Regulus of zinc effervеſces violently with ſaccharine acid and is ſoon covered with a white powder: this, in 100, contains 75 of metal, and is not ſoluble in water, unleſs when the acid predominates: the calx yields a ſimilar powder, and on the addition of acid of ſugar to ſolutions of zinc, in vitriolic, nitrous, or marine acids, a ſimilar powder is obtained.

§ XXIII.

### § XXIII. *Saccharated Antimony.*

Regulus of antimony grows black in digeſtion with ſaccharine acid, but the calx and the glaſs are diſſolved, though ſlowly.—The ſolution, in which the acid is always predominant, exhibits cryſtalline grains, which are ſcarcely ſoluble in water. The acid of ſugar precipitates ſimilar grains from acetated glaſs of antimony, but not from the butter; yet it takes antimony from the vitriolic acid.

### § XXIV. *Saccharated Manganeſe.*

Magneſia nigra efferveſces with acid of ſugar, even without heat; but the ſaturated ſolution depoſits a white powder ſcarcely ſoluble in water, unleſs the acid be ſuperabundant. This ſalt grows black in the fire, but again, upon the affuſion of acid, is turned to a milky powder, ſuch as is precipitated (mixed with ſome cryſtalline grains) upon the addition of ſaccharine acid, from the ſolutions of manganeſe in vitriolic, nitrous, or marine acids.

### § XXV. *Elective Attractions of Acid of Sugar.*

From the preceding experiments it appears, that the elective attractions of acid of ſugar are as follow, viz. Lime claims the firſt place (§ VI.); terra ponderoſa the ſecond (VII.); then magneſia (VIII.); vegetable alkali (III.); mineral alkali (IV.); volatile alkali (V.); and laſtly, clay (IX.) With regard to other acids, the ſaccharine acid yields alkalis to vitriolic, nitrous, and marine acids, arſenical acid, acid of fluor, and phoſphoric acids (III.); it yields lime to none (VI.); terra ponderoſa, to vitriolic acid (VII.); magneſia, to the fluor acid (VIII.); clay, to vitriolic, nitrous, and marine acids (IX.); ſilver (XII.) and antimony (XXIII.) to marine acid; lead (XIV.) and perhaps tin (XVII.) to the vitriolic; but mercury (XIII.), copper (XV.), iron (XVI.), biſmuth (XVIII.), nickel (XIX.), cobalt (XXI.), zinc (XXII.), and manganeſe (XXIV.), to none, ſo far as is yet known. As to the metals, though they are ſet down by all in the table of ſimple elective attractions, their forces being determined by precipitation; yet, properly ſpeaking, they do not belong to that place, as their precipitations are in fact performed by means of a double elective attraction.—If, however, any one wiſhes to keep them in that place, he may take it for granted that they preſerve nearly the ſame order, whatever menſtruum they are diſſolved in.

## § XXVI. *Whether Saccharine Acid owes its Origin to the nitrous.*

Hitherto we have conſidered the properties of the acid of ſugar; it now remains to ſay ſomething of its origin: and here a queſtion firſt occurs, whether it be truly and perfectly inherent in the ſugar, or whether it be generated during the boiling, by the adventitious nitrous acid? I do not deny but that, at firſt ſight, the nitrous acid appears to contribute ſomething to the generation of this acid, as all attempts to generate it without the aſſiſtance of that acid have hitherto failed. I once thought, that the nitrous acid, being very greedy of phlogiſton, is by that means able, during the proceſs, to ſpoil the ſaponaceous maſs of ſugar ſo far of its inflammable principle that it can at length give out its ſaline principle alone; yet I never could accompliſh this end, either by diſtillation of ſugar, or detonation with nitre; by digeſtion or decoction with vitriolic or dephlogiſticated marine acid; nor finally by manganeſe: however, although the experiments hitherto tried have proved fruitleſs, we are not authoriſed to conclude that there is no poſſible means of extracting the acid of ſugar without the help of nitrous acid; at leaſt, it cannot be proved by any probable, much leſs concluſive argument, that nitrous acid enters into the compoſition of the acid of ſugar,

ſugar.—Sugar is either ſpontaneouſly or artificially ſeparated from certain vegetable juices, and is therefore conſidered as an eſſential ſalt: now all ſuch ſalts, as we know, poſſeſs acids peculiar to themſelves; it will therefore hardly be denied that the ſame is the caſe with reſpect to ſugar, though we were ignorant of any other proofs. In common ſugar, the ſuperabundant acid is carried off in ſuch a manner during the preparation, as to eſcape the notice of our ſenſes: nevertheleſs thoſe converſant in chymiſtry can entertain no doubt concerning that which remains (*h*).

We conclude then that an acid does exiſt in ſugar: it remains to enquire, whether this be altered by the nitrous acid.

If we examine the operation with all due attention, we ſhall find that nitrous acid has ſuffered no other change than the following: it grows red, being loaded with phlogiſton, it becomes more volatile and more weak, and a part of it aſſumes the nature and properties of that elaſtic fluid now diſtinguiſhed by the name of nitrous air: again, nothing more is required than that the eſſential acid entangled in the oily part be ſet at liberty, and this is obtained in an highly active ſtate, (§ 1. G), although ſtill loaded with ſo great a quantity of phlogiſton as to exhibit cryſtals, while other acids, being deprived of that principle, are

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(*h*) The acid of refined ſugar is developed ſo as to make a ſenſible impreſſion on the teeth. Morveau.

always fluid; and this ſolid ſtate is competent to ſaccharine acid, even when further deprived of phlogiſton (§ III. I.) (*i*).

If we conſider the nature of the acid of ſugar, we ſhall find that it does not reſemble the nitrous acid

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(*i*) If it be in general true, that the concrete ſtate of the acids is owing to phlogiſton alone, neither the ſedative nor the phoſphoric acid, in a glaſſy ſtate, nor that of arſenic, can be free from it; yet the two laſt form with it ſolid ſulphur, as well as the vitriolic; and the ſolidity is probably owing to the ſame combination. On the other hand, a fluid form is eſſential to marine acid not dephlogiſticated; vinegar, though loaded with unctuous matter, cannot be obtained concrete; nitrous acid is changed by phlogiſton into gas, and the volatile vitriolic acid preſerves its fluidity. It appears indeed, that theſe laſt-mentioned combinations are modified by air, which cauſes the difference between ſulphur and the ſulphureous acid;—but theſe obſervations ought not the leſs to guard us againſt generalizing the principle. The analogy obſerved by the author may be very juſt, when conſidered with reſpect to ſome particular phænomena; and it is very poſſible that the fluid vitriolic acid may harbour as much phlogiſton as cryſtals of the ſaccharine acid before calcination: the more or leſs deſtructibility of a compound does not always indicate the proportion of the conſtituent parts: laſtly, the fluidity of acid is a real ſtate of fuſion, like that of mercury; this idea, which I had not conſidered (l. c.) but with reſpect to its connection with the general ſyſtem of the properties of bodies, is confirmed by the fine experiments of the Duke d'Ayen, on the congelation of the vitriolic acid in a temperature 15 degrees below the freezing point [2° or 3° below 0 of Fahrenheit's ſcale.]

Morveau.

acid in any other inſtance than thoſe properties which are common to all acids: beſides, it expels the nitrous acid from lime, terra ponderoſa, magneſia, and metals (§ XXV.); yielding to the other acids nothing but alkalis (§ III.). While the nitrous acid produces ſalts, either deliqueſcent or eaſily ſoluble, acid of ſugar yields ſuch as are ſcarcely ſoluble in water (§ VI. VIII. XII. XV. XVI. XIX. XXI.). Alkalis, when nitrated, detonate with ignited phlogiſton; but, when ſaccharated, ſhew not the leaſt ſigns of deflagration, which they evidently do upon the addition of the ſmalleſt particle of nitrous acid. The nitrous acid corrodes tin and antimony, but ſcarcely diſſolves them, while acid of ſugar readily acts upon them: phlogiſticated nitrous acid, united with vegetable fixed alkali, deliqueſces, does not form cryſtals, and is readily expelled by vinegar, or even by acid of ſugar, ſtill more loaded with phlogiſton: all which circumſtances by no means take place with reſpect to the fixed vegetable alkali united with acid of ſugar. Many other diſſimilarities will occur upon compariſon, ſo that theſe acids are of a nature not only unlike, but in many inſtances diametrically oppoſite. If any will attribute all the difference to phlogiſton, I will not deny, that that ſubtile principle forms a wonderful ſource of difference; but the differences which take place here can by no means be attributed to this when properly examined. The nitrous acid is weakened, and made far more volatile, by union with the phlogiſton; the acid of ſugar much more fixed, even when loaded with ſo great a quantity as to be cryſtallizable;—it almoſt every where expels the ſtrongeſt nitrous acid, as experiments ſhew; beſides, the phlogiſticated nitrous acid produces, with the very ſame matters, compounds totally different from thoſe with acid of ſugar. Nothing can be judged from circumſtances which are unknown, forged, or at beſt poſſible—and among all the facts yet known, concerning the acid of ſugar, we can find no ſigns of its being derived from the nitrous acid.

However, let us enquire more deeply; let us principally conſult nature, not indifferently and ſlightly, ſupplying the deficiencies with fiction, but candidly and properly, by apt and accurate experiments, otherwiſe her anſwers, like thoſe of the oracles of old, will be either deluſive or ambiguous.

But, by whatever means the acid of ſugar is produced, it muſt be conſidered as diſtinct and different from all others, being always eſſentially and ſpecifically the ſame. Its ſingular properties, ſome of which are of conſiderable uſe in chymiſtry, ſhew that it deſerves the moſt particular attention: from the time of Stahl, many conſidered the nitrous and marine acids as generated from the vitriolic; but if all confiding in this theory (which yet is contradicted by daily obſervation) had neglected the examination of thoſe acids, conſidering them as ſubordinate and derivative, we ſhould be to this day ignorant of many ſingular facts, which by degrees were diſcovered, principally becauſe many conſidered theſe acids as diſtinct and ſeparate ſubſtances (*k*).

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(*k*) To the hiſtory of the Acid of Sugar, accident, and the enquiries of later chymiſts, enable me to make addition.—Profeſſor Murray, of Gottingen, has affirmed, that Mr Schrikel has obtained it by repeated diſtillations and congelation, without uſing any nitrous acid. M. Morveau, from whom I learn this, adds nothing further concerning the proceſs. Was it in this caſe procured by diſtilling ſugar with the black calx of manganeſe, or the calx of lead, ſubſtances which attract the inflammable principle with conſiderable force? yet the author failed, as he did alſo in attempting to dephlogiſticate the ſaccharine acid by means of the dephlogiſticated muriatic acid. The experiments, however, mentioned by Profeſſor Murray, furniſh an irrefragable argument of the eſſential difference between the nitrous acid, and that of ſugar. Though the author's reaſoning, by every unprejudiced perſon, will be thought to prove this abundantly, there are ſome chymiſts of note, and teachers of chymiſtry, who maintain, that the ſaccharine acid is nothing but nitrous ſulphur.

" The Abbe Fontana has obtained an acid perfectly like that of ſugar, and ſaccharine ſubſtances, from all the gums and reſins." (Journ. Phyſ. tom. xii. p. 182. and tom. xiii. p. 23.). Morveau.

I have heard that it has been procured from oils; but the moſt intereſting diſcovery of this ſort was made by the celebrated Mr Watt of Birmingham:—he was, I underſtand, making ſome experiments relative to ink, when he obſerved a number of bodies floating in the fluid, which had the ſhape of cryſtals of the ſaccharine acid, and upon examination were found to be really ſuch: he found, by adding nitrous acid to galls, and conducting the proceſs in the way recommended by Profeſſor Bergman, that theſe aſtringent bodies contain the acid of ſugar in greater abundance than the ſubſtance from which it derives its name.—I cannot be certain that theſe circumſtances took place exactly as I deſcribe them, but I have reaſon to ſuppoſe that this account is near the truth. B. The acid yielded by an infuſion of galls, or by diſtilling them, according to a late diſcovery of Scheel's, is probably only a modification of the ſaccharine acid.

As to what is ſaid concerning acid of ſugar, procured by diſtillation and congelation, Dr Murray, or Mr Morveau, muſt have miſtaken the matter, Mr Schrickel did obtain an acid, by diſtillation, but very different from Bergman's, as may be ſeen in a paper of Crell's, among Mr Scheel's Eſſays. To obtain acid of ſugar, without vital air, or nitrous acid, would be a fact of great importance in the preſent ſtate of chemical theory.

# DISSERTATION IX.

## OF THE

## PREPARATION OF ALUM.

### § 1. *Various Uſes of Alum.*

NATURE produces but a very ſmall quantity of native alum; and this is mixed with heterogeneous matters, or effloreſces in various forms upon ores during calcination; but rarely occurs cryſtallized. In this latter ſtate it is reported to be found in Egypt, Sardinia, Spain, Bohemia, and other places; I have ſometimes ſeen it generated in the aluminous ſchiſt of Lapland and Weſt Gothland, by a ſpontaneous decompoſition of the ore; beſides, it is found diſſolved in the aerial waters: it is found, but very rarely, in fountains, and in hot medicated waters. —After having conſidered the various uſes of this ſalt, we ſhall examine at what time it firſt began to be artificially prepared.

In the diſpenſatories, alum enters many preparations, liquors, collyria, gargles, plaiſters, boluſes, pills, powders, and others: by its mild acidity it coagulates milk; and it, beſides, poſſeſſes a remarkable aſtringent power.

In the arts alſo, and the œconomy of private life, the uſe of this ſalt is very frequent; it is added to tallow to make candles hard. The printers cuſhions are rubbed with burnt alum that the ink may ſtick; and for the ſame reaſon the inſtruments uſed for printing linen. Wood ſufficiently ſoaked in alum does not eaſily take fire: the ſame is true of paper impregnated with it; which, for that reaſon, is very proper to keep gun-powder, as it alſo excludes the moiſture of the air. Paper impregnated with alum is uſeful in whitening ſilver and ſilvering braſs without heat; it is uſeful, added to milk, which does not eaſily ſeparate its butter; in the conglutinating of ſeveral ſubſtances; in making the pyrophorus; in tanning; and many other manufactures.

In the art of dying it is particularly uſeful, in the preparation of the matters to be dyed; for by cleanſing and opening the pores upon the ſurface by a gentle corroſion, it both renders the ſubſtance fit for receiving the colouring particles (by which the alum is generally decompoſed) and at the ſame time makes the colour fixed.

It conſtitutes the baſis of crayons, which generally conſiſt of the earth of alum, finely powdered and tinged for the purpoſe. This it is which, in the preparation of Pruſſian blue, prevents the baſis of the martial vitriol, which is ſoluble in acids, from being precipitated by the ſuperfluous alkali; that is, the alkali not ſaturated with the colouring matter. As this baſis adheres more ſtrongly to the vitriolic acid than the clay does; and as, by the mixture of its yellowneſs, it would form a green, the very white earth of alum alſo, according to its quantity, dilutes the darker colours, even black itſelf, and produces infinite degrees of intenſity. It is unneceſſary to ſay more of its uſeful qualities.

## § 11. *Brief Hiſtory of the Preparation of Alum.*

The στυπτηρια of the Greek, and the *alumen* of the Romans, was a native ſubſtance, and differed much from the ſalt which now goes by thoſe names. The varieties of alum mentioned by Dioſcorides refer to ſtalactites, which contained very little, if any, alum; and that completely enveloped by a vitriolic matter. The deſcriptions of Pliny are ſtill more difficult to be underſtood, as he had not ſeen the ſubſtances, the deſcription of which he undertakes, but merely tranſcribed from the writings of others.

The factitious ſalt, which is now called alum, was firſt diſcovered in the eaſtern countries; but when, where, and by what means, is unknown. On account of its ſimilarity in aſtringency, and its uſe in the arts of tanning and dying, the new ſalt has retained the old name, which was afterwards called miſy. ſory. calcanthum, or ſhoe-maker's black.

Among the moſt early works eſtabliſhed for the preparation of alum, we may juſtly number that of Roccho, a city of Syria, now called Edeſſa;—hence the appellation of Roch alum, a name which is generally ſo ill underſtood, that many to this day imagine that it is the ſame as rock-alum. In the neighbourhood of Conſtantinople there were many alum-works, as alſo at Phocæa Nova, now called Foya Nova, not far diſtant from Smyrna. The Italians hired and made uſe of many of theſe; but about the middle of the 15th century, they introduced the art into their own country, and that with the greater earneſtneſs, as the uſe of the ſalt became more frequent, and occaſioned the drawing large ſums of money out of the country.

Bartholomew Perdix, or Pernix, a merchant of Genoa, who had often been at Rocha, diſcovered the matrix of alum in the iſland of Iſchia, about the year 1459, and eſtabliſhed a manufactory there; at the ſame time John de Caſtro, who had viſited the manufactories at Conſtantinople, diſcovered a matrix at Tolfa, by means of the ilex aquifolium, which he had alſo obſerved to grow in the adjacent mountains of Turkey; and his opinion was confirmed by the taſte of the ſtones. The attempts made by the Genoeſe at Viterbium and at Volaterre, ſucceeded extremely well: the preparation of it in Italy ſoon increaſed wonderfully faſt; and the induſtry of the natives was much ſtimulated by an edict of Pope Pius II. prohibiting the uſe of oriental alum, and appropriating the revenue ariſing from that made in Italy to carrying on the war againſt the Turks.

But the art was not confined to Italy: in the 16th century a manufactory was eſtabliſhed at Alcmaron in Spain, in the neighbourhood of Carthagena, which ſtill ſubſiſts.

There were many manufactories in Germany in 1544, of which that at Schwemſel in Miſnia ſtill remains. Long ſince, in the time of Agricola, alum was boiled at Commotau in Bohemia.

The firſt manufactory in England was eſtabliſhed in the reign of Elizabeth, at Giſborough, by one Thomas Chaloner.

The art of preparing alum made its way into Sweden very late; and although we have now no leſs than ſeven manufactories, not one of them was founded before the 17th century.

The moſt ancient, eſtabliſhed in Scania at Andrarus in 1637, had twenty-two ſingle, or twelve double boilers. (We ſhall ſee hereafter what is meant by double and ſingle boilers). In this place the ſtratum of aluminous ſchiſt is very deep, being

ing upwards of 360 feet; but all the boilers are not uſed every year. In the year 1765, 2,735 ton of alum were manufactured; in 1766, 3,099; in 1767, 2,423; and in 1768, 1,427.—A ton of alum weighs 344 lb.

At Lofver, near Calmaria, in Smoland, another manufactory was built in the year 1721; there were employed in this, beſides one boiler for purification, only four double boilers, although the patent allowed five; much inconvenience being occaſioned by bringing the mineral from Ocland, and by the ſcarcity of wood. In 1765, there were made 1,020 ton; in 1766, 926; and in 1767, 800;—the average for ten years was 1,000 ton.

In Weſt Gothland there are four; the firſt at Mulltorp, near the town of Schæfde; this has only two ſingle boilers, and the ore is in the neighbourhood. In 1765 there were made 90 ton; in 1766 no more than 71.

At about half a mile's diſtance from Oltorp, in the diſtrict of Dimbo, a patent was granted in 1726, for three ſingle boilers; in 1765 were made 157 ton; in 1766, 300.

A third at Kaſvelas obtained, in 1748, a patent for two ſingle boilers; to which, in 1765, were added two more;—the ore is diſtant a quarter of a mile. This produced, in 1765, 312 ton; and in 1766, 293.

A fourth at Hænſæter in Kinckulle, obtained a right of two ſingle boilers in 1766;—the ore is found in the neighbourhood.

The greateſt manufactory was eſtabliſhed at Garphyttan, in Nericia, in the year 1766, with a privilege of ten ſingle boilers, which was increaſed to thirty in 1769. Here, while the matrix is burned, the boiling is performed by means of a peculiar conſtruction of the furnaces; and whether we conſider this manufactory with reſpect to the greatneſs of the works, the convenience of the apparatus, or the goodneſs of the alum (which even excels the Roman), we muſt acknowledge that it is beyond compariſon ſuperior to them all.

The diſtrict of Ljung, in Oſtro Gothland, has had for many years a privilege of boiling alum; but the work has not yet been ſet on foot.

Every thirtieth ton goes to the royal revenue.

A ſingle boiler is 5¼ feet in breadth, 11 in length, and in depth at the front 3, at the rear 2½, and contains 1,663 kannes, and 6 quadrants. The double boiler is of the ſame depth and length, but is ten feet broad, and contains 3,025 kannes.

## § III. *Proximate Principles of Pure Alum.*

(A) Alum is an imperfect middle ſalt, conſiſting of vitriolic acid and pure clay; it takes up a conſiderable quantity of water in cryſtallization; and, if the proceſs be not interrupted, yields octaedral cryſtals, which are tranſparent and colourleſs as water.

(B) The acid is a little ſuperabundant, ſo as to redden the tincture, and even the paper of turnſole. This exceſs of the acid is eſſential; for, upon taking it away, all the taſte, all the ſolubility, and all the original properties of the ſalt, are loſt (*a*).

The proportion of the principles is aſcertained in the following manner:—the water is expelled by a gentle heat; the remaining maſs grows opake,

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(*a*). M. Morveau will not admit a ſuperabundance of acid in alum: he thinks it would be neceſſarily ſeparated by edulcoration and cryſtallization, when it is no longer held by its affinity with the earthy baſe, or the ſalt itſelf, when it is formed. He thinks, that the change of blue vegetable juices to red is not an unequivocal proof of the preſence of an uncombined acid, an opinion which Mr Kirwan has alſo adopted. In the preſent caſe it ſhould be remembered, that we have certain proof that a portion of vitriolic acid adheres to the clay leſs tenaciouſly than the remainder. If a piece of iron be put into a ſolution of this earthy ſalt, it will attract this portion of acid, and the vitriolated clay will fall down inſoluble. Now we may preſume, that this looſely adhering acid produces the change on blue vegetable juices;—the ſame thing is true of phoſphorated calcareous earth. A ſolution of this ſalt will yield the ſuperabundant acid to a baſe which attracts it with far leſs power, and then the middle ſalt will be precipitated inſoluble; ſo that, in both theſe caſes, a quantity of acid above that which is required to attain the preciſe point of ſaturation, is neceſſary to ſolution and cryſtallization. B.

ſwells, foams, and at length remains quiet, ſpongy, and friable. The quantity of earthy baſis may be determined by precipitation with fixed or volatile alkali. In this way, 100 parts of cryſtallized alum are found to contain 38 of vitriolic acid, 18 of clay, and 44 of water: let it be obſerved, however, that the earthy precipitate is not totally deprived of its acid; for when the alkali is added, the ſuperabundant acid is firſt taken up, and thus a great part precipitates, its acid being diminiſhed, but not quite abſtracted; and hence the precipitate, by the aſſiſtance of fire, partly decompoſes ſeveral ſalts; and long continued digeſtion in an alkaline lixivium, is neceſſary to ſeparate all the acid.

(c) Chymiſts have differed in opinion concerning the nature and proper name of the earth of alum. Meſſrs Geoffroy and Hellot firſt extracted it from common clay; Dr Pott did the ſame, but ſeems to conſider it rather as a production than a ſeparation: at length the celebrated Margraaf, by experiments which deſerve well to be attended to, demonſtrated that all clay upon the ſurface of the earth conſiſted invariably of two principles mechanically mixed, one of which forms the genuine earth of alum, which is perfectly different from calcareous, gypſeous, or metallic earths, and from magneſia. I am not certain whether this may be derived from the calcareous earth: to determine this point I have made a great number of experiments of different ſorts, but have not thence been able even to form a conjecture. Vague ſimilitudes in certain properties are never ſufficient to determine a perſon who earneſtly ſeeks for truth, and is not ſhackled by hypotheſis.—Since then the earth of alum is found to poſſeſs different properties from other earths, it ought to be diſtinguiſhed from them; and, ſuppoſing it in reality derived from the calcareous or any other known earth, yet it requires the addition or abſtraction of ſome other principle; for the bare change of magnitude or figure in the particles will never account for ſo great a difference; and therefore the primitive and derivative earths (ſuppoſing them to be ſo) muſt be conſidered as diſtinct and ſeparate.

Beſides, as an equal quantity of the earth of alum may be extracted from a given common clay, by means of different acids, it muſt be only mixed with theſe clays; for if it was generated by the menſtrua during the operation, it would no doubt vary both in quantity and quality, according to the differences of the menſtrua: but the moſt accurate experiments prove the contrary, as they always procure the earth of alum the ſame in quantity and quality, and the very ſame reſiduum; and ſyntheſis, in this caſe, produces full conviction: for if the earth of alum, and a due proportion of ſiliceous earth finely powdered, be added together, they regenerate common clay.

It may be aſked, why the baſe of alum is conſidered as a pure clay?—The anſwer is, That earth which is called clay is chiefly diſtinguiſhed by its tenacious and plaſtic quality when moiſtened, by its cracking when dried, and finally by its acquiring a flinty hardneſs in the fire. Now, as theſe ſpecific properties do not depend upon the ſiliceous particles, (which are not capable of being either ſoftened or hardened), but ſolely upon the earth of alum, it appears moſt evident, that the ſiliceous particles might be abſent, and the argillaceous nature remain; and that therefore the reſiduum is that which conſtitutes the argillaceous nature. Pure clay, it is true, may occur in the bowels of the earth, but very rarely free from all ſiliceous particles; and the variety in the proportion of this latter ſhew plainly, that its preſence is only accidental: for the pure clay is very ſubtilely divided, and very readily mixes with and adheres to heterogeneous matters, as will readily appear upon examination; yet it is remarkable for the intenſity of its properties. Thus common clay often contains $\frac{1}{2}$, or even $\frac{3}{4}$ and upwards, of ſiliceous matter; yet the ſmall portion of pure clay which is preſent is able to impreſs its own character, and communicate its own qualities, to the whole maſs, ſo completely that no one can doubt of its argillaceous nature. By common conſent, that earth which, by mechanical waſhing, without the addition of an acid, depoſits upwards of 70 lb. in 100 of ſiliceous matter, is called clay. Now, it is evident that this foreign ſubſtance, by the largeneſs of its quantity, muſt temper the qualities of the pure clay. The argillaceous earth contracts by heat very much, even to half its bulk: hence, if it be uſed for cieling or plaiſtering, it neceſſarily cracks, and ſeparates from the walls, when a ſufficient degree of heat takes place; nor can it adhere to them, unleſs when fuſed, an operation which pure clay cannot be made to undergo, even in the focus of a concave mirror; but the addition of ſiliceous earth reſtrains the propenſity to contraction in the whole maſs, ſo that it remains of due dimenſion; and this property is well known to builders, who conſtantly avail themſelves of it (*b*). He who attempts to make well depurated earth of alum fuſible, by mixing it with

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(*b*) "Clay ſo much burned as to ſtrike fire produces the ſame effect as flint; which proves, either that flint ſerves like any other matter not capable of contracting, or that by burning clay approaches the nature of flint: it certainly undergoes a conſiderable change in the fire, as it loſes the property of being diffuſible in water. Such facts, known only by means of manufactures, afford very little inſight into nature, till chymiſtry has examined them carefully." Morveau.—That clay does not change its nature by being burned, appears evidently from an experiment with which M. de Morveau was ſeemingly unacquainted:—if hardened clay, ſuch as cannot be treated with water, be diſſolved in vitriolic acid, and then precipitated, it regains its former properties, and may be diluted by water. B.

common clay, either confounds the clays with others, containing not a particle of clay, or has never made the experiment.—The ſame is true of other pretended qualities :—alum ſwells, pure clay does not—the earth of alum, deprived of all its acid, and the precipitating alkali adhering to it, does not fuſe with calcareous earth, without the addition of a flinty matter, as the celebrated Macquer has ſhown; but we muſt take care that the calcareous earth contains no flinty matter, which ſometimes happens; for in this caſe the experiment will fail, becauſe the ſmalleſt particle of flint communicates a degree of fuſibility to the two ingredients.

(D) 100 parts of cryſtallized alum requires, in a mean heat, 1,412 of diſtilled water to diſſolve them, but of boiling water only 75; ſo that a kanne of water, in a moderate heat, takes up 2,992 grains of alum, and by a boiling heat 56,333.—This ſolution has a ſweetiſh aſtringent taſte.

The ſpecific gravity of alum, computed from the increaſe of bulk, or of diſtilled water into which it is put, is 2,071, if the air-bubbles produced during the ſolution be removed; but if they are taken into the computation, 1,757. This air is not taken away by the air-pump; but if heat be applied during the ſolution, it flies off, and upon examination is found to contain nothing but aerial acid.

§ IV.

## § IV. *Aluminous Ores.*

The ores from which alum is artificially prepared are of two kinds; the one contains the alum already formed, the other its proximate principles, which unite on roaſting. Theſe muſt be conſidered ſeparately;—and we ſhall firſt examine the latter ſpecies, as being beſt known, and moſt frequently met with.

(A) The aluminous ſchiſt is nothing more than an argillaceous ſchiſt impregnated with a dried petroleum, and thereby rendered black. The oil is eaſily extracted by diſtillation: if, by means of menſtrua, we analyſe it entirely, many ingredients appear; namely, an argillaceous martial ſubſtance, often amounting to $\frac{3}{4}$; a ſiliceous, forming $\frac{1}{6}$; and generally alſo a ſmall portion of calcareous earth and magneſia; the reſt is all pyritous.

During the roaſting, the bituminous part is expelled, and the pyritous decompoſed; ſo that a part of the acid adheres to the iron, and the reſt to the pure clay: hence are produced at once alum and green vitriol; and if there be preſent any calcareous earth, or magneſia, they are vitriolated.

Nothing ſaline is extracted by water from the ſchiſt before the roaſting, though it be well powdered; nor can the taſte diſcover any veſtiges of a ſaline matter: hence alſo it appears to be generated during the operation; and for that purpoſe nothing ſeems to be neceſſary but the preſence of a pyrites; this ſometimes ſhews viſible nuclei of different ſizes, but is generally diſperſed through the whole maſs, in the form of very minute particles: the goodneſs, therefore, of the ore, is to be eſtimated by the ſuitable quantity and equal diſtribution of the pyrites.

That which contains the pyrites ſo copiouſly that it is viſible, is rejected, there being too much iron in it—in the mean time, the moſt denſe and ponderous is moſt eſteemed; the weight manifeſtly diſcovering a pyrites, without which no alum is obtained. In this point there generally occurs a conſiderable difference, which ariſes, doubtleſs, from the unequal diſtribution of the pyrites: hence a ſtratum adjoining to one of the beſt kind, is often of little or no value. The ore which produces leſs than 4 lb. in 100 does not, with us, pay the expence of the proceſs.

Sometimes this ore produces ſalts without the application of fire; but we muſt obſerve, that in this caſe it is never found, but has undergone more or leſs of a ſpontaneous calcination.

A ſmall piece expoſed to fire upon a coal with a blow-pipe, often decrepitates; but when once made thoroughly hot, it ſmokes, with a bituminous ſmell, and eaſily melts:—with mineral alkali it effervеſces violently, and is divided, but not entirely ly diſſolved: it is taken up (though ſlowly) by the microcoſmic ſalt; but more quickly by borax: theſe phænomena are eaſily explained from its compoſition.

This ore is ſometimes found naturally divided, and heaped together, under the forms of grains, or of coarſe powder; but it agrees with the former in nature and properties.

(B) The other ſpecies of ore, which not only contains the proximate principles, but contains them united, is only found in volcanic countries; ſuch is that which is employed at Tolfa, near Cincelles, for boiling that ſpecies of alum which is called Roman alum;—it is probable that this had been long hardened by the ſubterraneous fire, and penetrated and whitened by the vapour of the phlogiſticated vitriolic acid (*c*): a ſtony maſs, with veins of quartz, and extremely hard, is alſo found in that country; that which is void of ſlavour very rarely produces alum upon elixation.

It ſometimes, though rarely, contains calcareous particles. I have ſeveral pieces, weighing in the whole at leaſt half a pound, in which there is not the ſlighteſt trace of any thing calcareous;—upon burning, it does not exhibit the leaſt reſemblance to lime: for it neither generates heat with water, nor falls into a powder, but only

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(*c*) De Productio Ignis ſubterranei.

cracks ſo much as to aſſiſt the eﬄoreſcence and elixation.

When examined by the blow-pipe, it does not flow of itſelf; with the mineral alkali, at firſt it ſhews a momentary efferveſcence, but is not divided, much leſs diſſolved; with borax and microcoſmic ſalt, it efferveſces, and is at length all taken up, exactly in the ſame manner as burned alum. Theſe phænomena abundantly ſhew, that the alum is ready formed, but inveloped in a large quantity of clay. This mineral, therefore, reduced to a ſubtile powder, and treated in the uſual way with vitriolic acid, is almoſt all converted into alum, which could not be the caſe with calcareous earth.—I found that the ſmall portion which remains is more frequently ſiliceous than gypſeous (*d*).

At Solfatara, near Naples, the old lava is at preſent whitened by the phlogiſticated vitriolic acid, the clay is changed into alum, the maſs eﬄoreſces, and is reſolved into a white earth, from which a ſaline matter is extracted by water. I examined 100 of the white earth, and found in it

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(*d*) " According to Mr Monnet, it does not contain alum perfectly formed; but is a combination of nearly equal parts of clay and ſulphur, which is reduced to alum during calcination, by expoſure to air. He likewiſe found a little martial earth, to which he aſcribes the reddiſh colour of the alum, and a little vegetable alkali." (*Journal Phyſique, Supplement, p.* 338.). Morveau.

8 lb. of perfect alum, beſides 4 of pure clay, and the reſidue was ſiliceous: but this proportion muſt be variable, as rain diſſolves and carries off the ſalt; ſo that the proportion of ſiliceous matter continually encreaſes, and perhaps in ſome parts the alum is entirely waſhed away.

(c) There are found alſo other varieties of aluminous ores. In Haſſia and Bohemia, this ſalt is obtained from wood impregnated with bitumen. At Helſingborg, in Scania, a turf is found, conſiſting of the roots of vegetables, mixed with nuts, ſtraw, and leaves, often covered with a thin pyritous cuticle, which, when elixated, yields alum; nay, the ſulphureous pyrites is generally mixed with an argillaceous matter, which may be ſeparated by menſtrua. To that at Dylta, in Nericia, when ſulphur is firſt obtained by diſtillation from the pyrites, and afterwards from the reſiduum expoſed to the air, till it effloreſces, a green vitriol is elixated; at length, from the magiſtral lixivium alum may be obtained: for the vitriol being ſeparated by cryſtallization, there remains alum, together with vitriol ſo much dephlogiſticated, that it cannot concrete; the baſe of this, therefore, was ſeparated by the alkaline lixivium; and the ſolution, properly evaporated, yielded alum.

## § v. *The Preparation of Alum includes a Number of Operations.*

After the foregoing obſervations, we ſhall be able the more eaſily to underſtand the different circumſtances neceſſary for the preparation of alum. The mechanical parts of the proceſs I paſs over, as not immediately belonging to our ſubject. The firſt chymical operation which occurs is one of the chief; namely, the preparation by which the matrix is either made aluminous, or at leaſt fit for elixation: the next is, the extraction of the alum by water, then the cryſtallization, and finally the depuration; unleſs all the operations be performed both with ſkill and accuracy, the alum obtained will be deficient either in quantity or quality: we ſhall therefore examine them all ſeparately, and, by diving as far as poſſible into the nature of them, diſcover the circumſtances neceſſary to be attended to.

## § vi. *The Calcination and Roaſting of the Ore.*

The bituminous ore, in its ſound and natural ſtate, contains indeed the vitriolic acid, and the argillaceous matter, but not yet combined In order that the pyrites may yield its acid for that end, it is neceſſary that it ſhould be deſtroyed;

and this may be effected, either by a ſlow ſpontaneous calcination, or by roaſting; which laſt requires leſs time.

(A) The deſtruction of the pyrites its neceſſary, that its ſulphur may be deprived of phlogiſton; for when that is diſſipated, the vitriolic acid being ſet at liberty, attacks partly the iron, partly the clay: the vitriol generated is ſo far deprived of its phlogiſton by age, that clay is able to take away the menſtruum from the iron (x. B), but pyrites ſuffers no ſuch change, ſo long as it remains dry, and ſhut up from the acceſs of free air;—the conditions then neceſſary to ſpontaneous calcination are eaſily found to be the following:

1ſt, The ore ought to be of a looſe texture, that it may be penetrated by the air, and the moiſture: the Swediſh ores, on account of their hardneſs, can ſcarcely be treated in this way, unleſs they be firſt pulverized, which occaſions too much trouble: but the earthy ores are not only unfit for this purpoſe, but for roaſting, as they extinguiſh the fire.

2dly, That there be a determinate acceſs of moiſture and air, for too much or too little is injurious;—too much water deluges the maſs, and excludes the air; too little, beſides being inſufficient in quantity, acts more ſlowly; and upon theſe circumſtances depends the proper adjuſtment of the ſize of the heaps: a moderate acceſs of air is moſt proper, as too great a one dries too

faſt;

faſt; experience only can determine what is fitting upon different occaſions.

3dly, The bottom on which the ore is laid for ſpontaneous calcination ſhould be of clay, or at leaſt ſo compact as that water can hardly penetrate it, and beſides ſurrounded with a trench to receive the rain-water, when ſuperabundant; the ſides and bottom of this trench muſt be ſo conſtructed that they will not ſuffer the elixated ſaline matters to paſs off;—if the ore be ſet to calcine in a houſe, the laſt caution is unneceſſary. As the nature of the ores, and local circumſtances, are liable to much variation, general rules cannot be eſtabliſhed, but the operator muſt be determined *pro re natâ;* and in this, whoever underſtands the nature of the materials, and of the operation, will find no difficulty.

(B) The roaſting is effected in a much ſhorter time, by means of fire. This is generally practiſed in Sweden, and is performed in the following manner:—ſmall pieces of the black ſchiſt are ſtrewed upon a layer of burning ſticks, to the thickneſs of half a foot; when the ſticks are conſumed theſe are covered, nearly to the ſame thickneſs, with pieces before burned, and four times elixated: thus ſtrata are alternately laid of ſuch a thickneſs, and at ſuch intervals of time, that the fire may continue, and the whole maſs grow hot and ſmoke, but not break out into flame; the upper ſtrata may ſometimes be encreaſed to a double thickneſs, on account of the long continuance of the fire;—when about 8 ſtrata are laid, another row is placed parallel and contiguous to the firſt; when this is finiſhed, a third; and ſo on, until the heap is of a proper ſize—it rarely conſiſts of more than 10 rows. The ore, when only once roaſted, contains ſtill ſo much phlogiſton, that water acts but little upon it; but when two or three times expoſed to the fire, it yields its principles more freely;—nay, the roaſting may be repeated to advantage, until the whole is reduced to powder. The bitumen ſuſtains the fire, and it is for this reaſon that we uſe alternate layers of the crude ſchiſt; and for the ſame reaſon, in rainy weather, the ſtrata of unburned ſchiſt ſhould be thicker. An heap 20 feet broad at the baſe, 2 feet at the top, and conſiſting of 26 rows, is finiſhed in two or three weeks, but requires two or three months to be well burned, and three weeks to cool;—the greater pyritous nuclei explode like bombs.

By a moderate and ſomewhat ſmothered fire, the ſulphur of the pyrites is ſlowly conſumed, and the phlogiſticated acid, penetrating the maſs, is fixed; after which the remaining phlogiſton is gradually diſſipated. The chief artifice is moderating the heat ſo as to avoid with ſafety the two extremes; namely, leſt, on the one hand, the ore be either inſufficiently or too ſlowly prepared by a weak heat; and on the other, leſt either the neceſſary acid be diſſipated by too intenſe a fire, or the pieces of ſchiſt melt and vitrify. The ſcoriæ cannot be penetrated by water, and are therefore rejected as uſeleſs; theſe are occaſioned either by violent winds, or a ſtrong heat, too much cloſed; for holes muſt be opened in the red ſtrata, that the fire may reach to the black ſtratum which is to be laid on.

At Garphyttan a new method is employed, depending upon a peculiar conſtruction of the furnaces, invented by the celebrated Rinman.—There the ore itſelf is ſet on fire, and when burned is boiled, and yields alum in the ſame manner as when burned in the uſual way: I have not yet had an opportunity of comparing the ſalts produced by theſe two methods;—it appears probable that more of the acid is diſſipated by the open flame: however, although leſs ſalt be obtained in the laſt way, yet, with reſpect to fuel and labour, there will be a conſiderable ſaving.—The heaps are thus formed:—firſt the ſchiſt, burning from the furnace, is laid to the depth of four feet; if the fire be ſlow, wood is added; then a thin ſtratum of elixated ſchiſt; the third conſiſts of ſchiſt not burned; and the fourth of elixated ſchiſt, a foot and a half thick; after that the burning ſchiſt; and ſo on as before.

It muſt be confeſſed, that the conveniencies in this proceſs are ſomewhat balanced by inconveniencies; for ſo great a quantity of ſchiſt is requiſite to ſuſtain the flame, that it cannot all be elixated: hence, ſo long as this method is employed, we have an heap, which can never be uſed, perpetually accumulating.

In ſome foreign manufactories fire is firſt employed, and afterwards ſpontaneous calcination: it is impoſſible to determine generally which is the beſt method, as that entirely depends upon the nature of the ore, and other circumſtances.

(c) As to the hard ores which contain no bitumen (ſuch as thoſe of Tolfa) theſe are burned upon wood for ſome hours, like lime-ſtones, until by cracking they grow pervious to water, and effloreſce. As ſoon as the flame grows white, and the ſmell of phlogiſticated vitriolic acid appears, the fire is extinguiſhed. When the ore grows cold thoſe particles which were neareſt to the fire are placed outermoſt, and thoſe which had been outermoſt, within; and the fire is again lighted. It is better to burn too little than too much, leſt the vitriolic acid be expelled: the ore is ſufficiently burned when it can be broken by the hands.—The ore is then heaped up near certain trenches, and is watered about five times a day, and particularly when the ſun ſhines clear; a continued rain and cloudy ſky ruin the operation. When the ore can be reduced to a paſte in the hand, it is fit for boiling (*a*).

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(*a*) The accounts differ. Mazeas ſays, that water is poured on the burnt ore 14 days (*Scav. Etrang.* t. v.) Fougeroux, The powdery ore ſometimes requires no preparation, yet at the manufactories of Puteoli they frequently enrich it in this manner:—they heap up the larger pieces, where the vapours of phlogiſticated vitriolic acid break forth, and when well penetrated with this, they yield a larger quantity of alum.

## § VII. *Elixation of the Ore.*

(A) The ore, enriched with alum, and made pervious to water, is boiled, and that in various ways at different places.—At Puteoli it is performed in the moſt commodious manner: a leaden cauldron, buried in the ground, is filled with the ore (which is often dug out to make room for the cauldron) and water being poured on, it ſoon becomes well impregnated with alum by the heat of the ſun, which here ariſes to 46° (*b*). At Tolfa the calcined ore is thrown into the cauldron, and boiled.

(B) In ours, and many foreign manufactories, a cold elixation is performed. I ſhall give ſome account of the method which was uſed at Gar-

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Fougeroux, whom I have generally followed, ſays 40 (*Mem. Paris*, 1766; Angerſten, 14, and at moſt 20. So alſo with reſpect to the time of burning, Ferber ſays it is 3 hours, Fougeroux 12; and he mentions that it is repeated. Ferber ſpeaks of urine and chalk being added, &c. Perhaps the proceſs was different at different times.

(*b*) Nollet Mem. Paris, 1750.

phyttan, in the year 1772:—the receptacles deſtined for this purpoſe were made of hewn ſtone, and the joints cloſed by ſome fit cement (in other places they are wooden veſſels); every ſet conſiſted of four ſquare receptacles diſpoſed in a ſquare, round a fifth, which was deeper than the reſt; the firſt receptacle is filled with roaſted ſchiſt, and (water being poured on it) lies for 24 hours; the water is then drawn off by a pipe into the fifth, from thence into the ſecond, containing ſchiſt not yet waſhed; from that, in like manner, after 24 hours, through the fifth into the third, and ſo into the fourth; the lixivium then is conveyed to and let to ſtand in the fifth; and finally, from thence is drawn off into a veſſel appropriated to its reception:—thus the ſchiſt is waſhed with freſh water four ſucceſſive times.

In other places (and originally at Garphyttan) the water firſt paſſes over the ſchiſt that has been already waſhed three times for ſix hours, then that which has been twice waſhed, next what has been once waſhed, and laſtly, the ore that has been juſt roaſted. The perſons who ſuperintend theſe manufactories think that the alum, which the water firſt paſſing over the new burnt ſchiſt takes up, periſhes if it be again poured on that previouſly elixated.—This phænomenon, if it be true, is worthy of attention; but I have not had an opportunity of examining it.

(c) Care ſhould be taken to ſave fuel as much as poſſible; it is therefore of great moment to have the lixivium, before boiling, richly impregnated with alum; for the more rich it is when poured into the boiler, the ſooner it is cryſtallized: it ſhould not therefore be put into the boilers until ſaturated when cold. This ſaturation is neglected in ſome places, where every thing is tranſacted without deviating from the manner firſt uſed; in other places the taſte is employed as a criterion; but thoſe who examine more accurately, make uſe of a balance in this manner:—the weight of water which fills a ſmall glaſs bottle is divided into 64 parts, each of which is called a *panning;* and the quantity by which the ſame bottle, full of lixivium, exceeds it when filled with water, is ſuppoſed to indicate the quantity of ſalt diſſolved: and thence they form their judgement (*c*).

This method, properly corrected, is ſufficiently accurate.—The diviſion into parts is arbitrary; but the moſt commodious diviſion with reſpect to the weights in uſe, and the calculation, ought to be choſen: I ſhall therefore give ſome general formulæ:—let the capacity of the bottle expreſſed in cubic inches be m; n the number of parts into which it is thought proper to divide it: let a cubic inch of diſtilled water weigh 422,5 grains; then

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(*c*) Act. Stockholm, 1743.

the weight of one panning will $= 422{,}5\,\frac{m}{n}$; that of the whole capacity filled with water $422{,}5\,m$; that of alum of the ſame bulk as a panning $= 874{,}9\,\frac{m}{n}$: when the lixivium which fills the bottle is $= 422{,}5\,m + 422{,}5\,\frac{m}{n}$, it is then immediately concluded that the quantity with which the water is loaded is $= 422{,}5\,\frac{m}{n}$; but erroneouſly, for recent experiments ſhew, that ſalts diſſolved always (*d*) increaſe in bulk; and if this be always done in the ſame proportion, and the whole increment be ſet down aluminous, $422{,}5\,\frac{m}{n} + 452{,}4\,\frac{m}{n} = 874{,}9\,\frac{m}{n}$, will expreſs the true quantity diſſolved. And in general if p denotes the number of pannings found in the ſcales, the alum contained in the bottle will be $874{,}9\,\frac{mp}{n}$, and in the kanne $87{,}490\,\frac{p}{n}$.

But to return to the common practice:—the perſons who ſuperintend the works contend, that the cold lixivium ought to be made no richer than when the ſuperpondium is equal 45 pannings, which, according to our computation, ſhews the water to be loaded with $\frac{1}{5{,}7}$ of its own weight. They aſſert, that if the ſuperpondium amounts to 6 pannings, which is $\frac{1}{4{,}8}$, the cryſtals are depoſited. Theſe propoſitions cannot hold equally good during the whole time that the work is going on, as

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(*d*) R. Watſon. Phil. Tranſ. 1770.

the temperature of the atmoſphere varies much during that time. We ſhewed before that diſtilled water, in a moderate heat, takes up about $\frac{1}{14}$ of its own weight, which, upon computation = $2\frac{1}{2}$ pannings, therefore $\frac{1}{5,7}$ cannot be taken up, unleſs in a heat more than moderate. But we muſt obſerve, that in the bituminous minerals, beſides the alum, there is always vitriol of iron, which is more ſoluble; there is alſo ſometimes vitriolated magneſia; and beſides, the more ſubtile earthy particles, mixed mechanically during the operation, remain long ſuſpended, unleſs the lixivium be filtered.

The water is generally impregnated by a ſufficient quantity of the prepared ore: it ſeems probable that more would be obtained by hot than by cold water; but this is denied by thoſe who daily attend theſe operations (*e*).

(D) From what has been ſaid it appears that the gradual operation, as it is called, can hardly be uſed to advantage in the alum works, as, of all the contents of the lixivium, alum is the moſt difficult of ſolution.

Congelation is here of no uſe; for water ſaturated with alum freezes almoſt as readily as ſimple water: and all other ſalts prevent congelation more than alum.

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(*e*) M. Morveau wonders that an aerometer is not employed, in order to determine the concentration of the ley. B.

In rainy weather the lixivium ought to be well covered; but I do not find in any manufactory proviſion made for this accident.

## § VIII. *Decoction of the Lixivium to Cryſtallization.*

Let us now ſuppoſe the firſt ſpring boiling beginning: the freſh lixivium, of a proper ſtrength, is brought from the pits, through canals made for the purpoſe, to the houſe deſtined for the boiling; there it is put into a leaden boiler; at the back of this is placed a receptacle, out of which the loſs ſuſtained by evaporation is continually ſupplied; ſo that by this artifice the ſurface of the lixivium in the boiler neither riſes nor falls, but continues at the ſame height.

Some take the floating of a newly laid egg as a token of boiling being finiſhed.—The ſpecific gravity of ſuch an egg is about 1,081; but in a few days, eſpecially in warm weather, it ſuffers a conſiderable change:—but ſuppoſing its ſpecific gravity conſtant, yet a conſiderable difference will occur, unleſs the magnitude of the part above the water be aſcertained.

Others drop a ſmall quantity on a plate, and obſerve whether it cryſtallizes on cooling.

Finally, others weigh the lixivium in the bottle above mentioned, and conſider the boiling finiſhed, if the increment of weight be equal to 20 pannings; that is (according to our computation) if the water be loaded with $\frac{1}{169}$ its own weight. Now we ſaw that it could take up above $\frac{1}{3}$ its own weight (§ 11.) that is, nearly equal to 27 pannings; but the lixivium cannot be ſo much loaded, as it muſt be depurated by ſtanding quiet, before any cryſtals form (*f*).

The lixivium, ſufficiently concentrated by evaporation, flows through channels into coolers, where

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(*f*) Nothing would be more advantageous for judging with preciſion concerning the degree of boiling which the leys have undergone, than the aerometer. This inſtrument ſhould be made of metal, that it might be leſs liable to be broken; it ſhould have ſufficient ballaſt, that it might ſink into the liquor, and ſtand upright; and after having once marked upon the ſtem the degree at which it ſtands in a ley ſufficiently concentrated, it might be hit again with certainty, and the ſlighteſt inſpection would be ſufficient. I contrived ſuch an one ſix or ſeven years ago for a ſugar refinery; a proceſs in which the degree of boiling is ſtill more important. This was determined before by putting a drop of the liquor upon the nail, and drawing it out into a filament, to expoſe it more completely to the contact of the air; inſomuch that the moiſture, heat, and agitation of the atmoſphere, beſides other accidental circumſtances, concurred to render this ſign very equivocal. The conductor of the work aſſured me, that this inſtrument had been very uſeful to him; and I know that it was afterwards introduced into other refineries. M. Baumé had before adviſed the uſe of it, in order to judge of the inſpiſſation of ſyrups (*El. de Pharmacie*, p. 555.). Morveau.

where, in about an hour, it is freed, by depoſition, from the groſſer heterogeneous particles; it is then put into either ſtone or wooden receptacles. In eight or ten days the lixivium, commonly called magiſtral water, flows into another veſſel, leaving behind a number of cryſtals, generally ſmall and impure, which incruſt the bottom and ſides of the veſſel. Theſe are collected, and waſhed from the impurities which adhere externally, with cold water: the impurities remaining in the reſervoir after waſhing, are kept by themſelves.

(B) The waſhed cryſtals are put into the boiler uſed for depuration, and are diſſolved in a quantity of water ſo ſmall that it may, when boiling, be able to take up all the ſalt, and be ſufficiently loaded with it: the lixivium is then poured out into a great tub, which holds the ſame quantity as the boiler does. After 16 or 18 days the hoops of the tub are looſed, and the aluminous maſs is bound with an iron ring: after 28 days the reſiduum of the ſolution is let out through a hole, and collected in a trench; the aluminous maſs, then dried, is called depurated alum, and amounts, at Garphyttan, to 26 tons.

(C) Let us now look to the boiler emptied for the firſt cryſtallization. This is directly filled two thirds with the magiſtral lixivium, which is brought to the boiling point; and as ſoon as it arrives at that, the empty third is loaded with the crude lixivium, with which alſo the waſte of evaporation is continually ſupplied. The boiling being finiſhed, ed, a certain quantity of aluminous impurities is added, after the ſolution of which, by continual agitation, the lixivium is let out as before. The firſt boiling in the ſpring, is performed with the crude lixivium alone; the reſt in the way above deſcribed.

As to the time required for cryſtallization, it may without doubt be ſhortened, eſpecially when the ſurface is ſmall with reſpect to the maſs, as is the caſe in our manufactories; for the reſervoirs uſed in the firſt cryſtallization are deep and very narrow at the top, and the ſame is the caſe to this day in the ſecond cryſtallization. The heat of the maſs, therefore, being reduced to the temperature of the ſurrounding atmoſphere, the evaporation, and of conſequence the depoſition, is very ſlow, except when the weather is exceeding warm, and beſides the doors and windows ſo diſpoſed that a current of air continually runs along the ſurface. The caſe is quite different in ſmall experiments, eſpecially in conical glaſſes, where the ſurface is very large with reſpect to the maſs. In Italy conical reſervoirs are uſed, and indeed with the greateſt propriety.

(D) In order to obtain the alum more pure at the ſecond cryſtallization, in ſome places additions are employed, ſuch as alkalis, lime, or urine; for the experience of many years has ſhewn, that the lixivium ſometimes acquires ſuch a conſiſtence, that it both cryſtallizes with difficulty, and produces impure cryſtals: pot-aſhes, particularly, were uſed to prevent this inconvenience, becauſe the acid is ſuperabundant. Pot-aſhes and lime, either burnt or crude, abſorb the acid; and, if added in proper propoition, diminiſh the quantity of heterogeneous noxious matter, by precipitating them: this will appear clearly, from conſidering the nature of the lixivium; but urine has no effect, except in ſo far as it contains volatile alkali. It is not to be denied, that new ſalts are in this caſe mixed; namely, vitriolated vegetable alkali, or others, according to the nature of the additament; theſe are undoubtedly more harmleſs than thoſe which are taken away, but yet are not to be ſold for alum.

(E) The Roman alum has been conſidered as the beſt ſort: at Brunſwick ſome time ſince they began to manufacture a ſpecies of alum, which, if we give credit to report, may properly be ſubſtituted for the Roman. I have examined this alum chymically, and found it mixed with cobalt (*f*). I have no doubt but the ore of cobalt roaſted, is mixed with the lixivium; for in that caſe the diſengaged acid attacks the metallic calx, and forms a roſe-coloured ſolution, which gives a tinge to the cryſtals. This alum, diſſolved in water, yields, upon adding a fixed alkali, an urinous ſalt; with phlogiſticated alkali, diſcovers iron, but not cobalt; which laſt is manifeſted by the violet colour, on fuſing the precipitated baſe with borax: —it is

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(*f*) I ſee that Erxleben has obſerved this in his Eſſays.

diſtinguiſhed from the Roman alum by its cryſtals, which are all tinged, acerb, and leſs acid than the Roman. A cryſtal of Roman alum expoſed to heat by the blow-pipe, ſoon grows opake, ſwells, and foams, but a ſpongy, immoveable, white maſs ſoon appears; whereas the Brunſwick ſwells leſs, hardly foams, but melts, and at laſt grows green; beſides, from the very beginning, it ſends forth copiouſly an arſenical ſmoke.

I do not deny that I have ſometimes got a green glaſs from the roſe-coloured baſe of alum, which would indicate the preſence of cobalt, if it always happened; but after once finding it, I have tried 100 times again to no purpoſe: what this colouring principle is, is ſtill doubtful; but we know for certain that the goodneſs of the alum does not depend upon it.—I have not yet had an opportunity of examining the uſe of Brunſwick alum in dying (*g*).

(F) At Tolfa the lixivium, agitated in a veſſel,

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(*g*) I have already mentioned Mr Monnet's conjecture concerning the cauſe of the reddiſh colour of Roman alum. By analyſing the beautiful red ſelenite from Montalier in Franche Comté, which is cryſtallized in ſhining lamellæ, and from which I have obtained iron in its complete ſtate, I am convinced, not only that this metal can communicate all the ſhades of this colour, but alſo that it adheres very tenaciouſly to vitriolic earthy ſalts; for, after boiling this ſelenite in diſtilled water, and filtering the ſolution, a depoſition, having a ſlight tinge of this kind, took place as the liquor cooled. Morveau.

is inſpiſſated by boiling for 24 hours (*h*); this being done, the fire is extinguiſhed, the earthy parts are taken away by inſtruments provided for the purpoſe, and the liquor, after being cleared by ſubſidence, is let out by a cock into a receptacle made of oak; there it cryſtallizes for 14 days; it is then let off into ſhallower receptacles, where it depoſits more cryſtals; and, finally, is let out in the magiſtral trench. In this proceſs no depuration is effected by cryſtallizing; and therefore the Roman alum contains in 100 lb. upwards of 5 lb. of a roſe-coloured earth:—100 of the ore never yields 2 lb. of alum.

The magiſtral lixivium appears unctuous, and difficultly forms cryſtals; yet, in broad and ſhallow veſſels, it yields genuine alum, although a ſlow ſpontaneous evaporation is neceſſary.

At Puteoli the lixivium digeſted by the ſolar heat forms at length on the ſurface cryſtals, which, being collected in a conical ſtone receptacle, are again diſſolved in warm water; and there, the evaporation going on by the natural heat, more pure cryſtals are formed: in this caſe the ore yields more than 40 lb. of alum in 100, but generally mixed with iron.

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(*h*) Travellers do not agree concerning the metal of which the boiler is made. Angerſten ſays that the bottom is of copper, and the ſides of ſtone, Ferber mentions copper only, Fougeroux ſays the bottom is of lead, Mazeas, that the boiler is of lead.

## § IX.

In order to diſcover the differences of the ſeveral lixivia more accurately, I began by examining the three principal; theſe are, that which is made of the roaſted ore, ſaturated with ſalt in the cold, and which is called the crude lixivium; that lixivium which remains after the ſecond cryſtallization of the alum; and, finally, the laſt lixivium, which is commonly called magiſtral. Theſe lixivia muſt neceſſarily differ more or leſs in different places, according to the nature of the ore employed, and the varieties of the operation: and even ſuppoſing the ore to be the ſame, and equally roaſted, yet the firſt is the richer, from the greater heat of the atmoſphere; the ſecond, through the whole year ſuffers the ſmalleſt variation; and the laſt the greateſt, as being from the beginning of ſpring till late in autumn, continually loaded with foreign matters; therefore, although a great variety neceſſarily occurs, yet it will be uſeful to conſider a ſet of experiments which were made upon lixivia got at Garphyttan in the month of September 1776, and carried well corked to Upſal.

(A) The ſpecific gravity of the crude lixivium, in a moderate heat, was to that of diſtilled water as 245 to 215: this ſpecific gravity indicates 9 pannings.

At the bottom of the bottle was collected a yellowiſh powder; the lixivium was yellow, a little greeniſh, had an aluminous taſte, but ſomewhat auſtere and earthy. Paper tinged with turnſole grew red when wetted with this lixivium; but the deep blue paper uſed for ſugar was not changed.

Phlogiſticated alkali immediately precipitated a Pruſſian blue, in the proportion of 930 grains to the kanne: this indicates nearly 809 grains of vitriol.

Fixed alkali, dropped in by degrees, precipitated firſt a ferruginous yellowiſh powder, then a white one; but that which falls on the addition of a few of the firſt drops, is by degrees again diſſolved; hence we may judge of the ſuperabundance of acid;—how great that ſuperabundance is, we ſhall ſee in the ſequel:—the acid of ſugar occaſioned no change.

In this lixivium there are preſent vitriol, alum, and vitriolated magneſia; ſalts which are not ſeparable from one another, but with great difficulty. I firſt tried to effect this ſeparation by ſpontaneous evaporation; when this can be done, diſtinct cryſtals generally appear (a very long time is indeed requiſite); and, in the mean time, the atoms which float in the atmoſphere mix with the liquor; but to avoid theſe inconveniencies, I uſe broad veſſels, which expoſe a large ſurface to the air; and as evaporation proceeds, *cæteris paribus*, in proportion to the ſurface, the delay is much diminiſhed. In order to exclude duſt, a very thin ſilk, or a large glaſs bell, may be put over the liquor: by this method I obtained from a kanne of the lixivium 1;933 grains of cryſtallized alum, and of a ſhapeleſs acid ſaline maſs, 5,790 grains; theſe were dried upon bibulous paper;—even the cryſtals themſelves, upon the addition of phlogiſticated alkali, yielded Pruſſian blue; I therefore tried another method of ſeparating the ſalts, and that with better ſucceſs:—

I firſt precipitated the iron with phlogiſticated alkali, then the earthy part with fixed alkali, in order to take up the ſuperabundant acid; I again diſſolved this earth, when waſhed, in vitriolic acid, the gypſum remained at the bottom; I weighed the liquor, filtered, cryſtallized, and dried; I totally deſtroyed the aluminous part of the ſalt remaining, by chalk; and, finally, filtered and cryſtallized the liquor which remained; this produced nothing but vitriolated magneſia.

I determined the quantity of ſuperabundant acid in the following manner: I added ſmall pieces of cryſtallized ſal ſodæ, theſe ſoon grew red from the precipitated iron, but were ſoon diſſolved: I continued to add the alkali, until ſome remained undiſſolved; at the ſame time I ſaturated a known weight of that vitriolic acid, commonly called oil of vitriol, with the ſame alkali, and hence learned to compare the ſuperabundance with the quantity of this oil.

Theſe experiments ſhewed that there were, in each kanne of the crude lixivium, 15 grains of gypſum, 3,889 of vitriolated magneſia, 2,933 of alum, 809 of martial vitriol, and ſo much diſengaged acid as was equal to 72 grains of common oil of vitriol.

The vitriol of iron which appears here is of a peculiar nature, for the lixivium does not depoſit an ochre on boiling, or on ſpontaneous evaporation to dryneſs, but holds its colour perfect; yet that it contains iron very much dephlogiſticated, is eaſily gathered from the ferruginous colour of the martial precipitate, occaſioned by a fixed alkali: the caſe is very different with a ſolution of common vitriol.

## § X.

From the preceding paragraph, it evidently appears, that there is preſent in the lixivia a greater quantity of acid than is neceſſary for the formation of alum. The queſtion is, whether this impedes the cryſtallization, or promotes it? Many, among whom is the celebrated Margraaf, aſſert the former; but an experiment publiſhed in 1744, by Mr Baron, ſuggeſted the latter opinion to ſome.—The experiment is this: concentrated vitriolic acid, added in large quantity to a ſolution of alum, precipitates the alum, by ſeizing the water; which being quickly cryſtallized in this intenſely acid ſolution, frequently exhibits cryſtalline ſpiculæ, or needles diverging from a point, like ſtars. This, in the ſame circumſtances, happens to many ſalts: — highly concentrated vitriolic acid is able to take away from alum not only the water of ſolution, but the water of cryſtallization. Let a tranſparent piece of alum be put into ſuch an acid, and in a few minutes it will be found to grow white and opaque: thus we have what may be called alum calcined by the humid way; and this phænomenon is a teſt of the perfect concentration of vitriolic acid.

But in the preſent caſe there is no queſtion of ſo great a quantity of acid as is able to take away from the ſalt its diſſolving water: the moſt highly concentrated vitriolic acid ſeems to be ſaturated with about double its weight of water (at leaſt it attracts no more from the atmoſphere): but we are now enquiring concerning a quantity which has united to it far more than twice its weight of water, which therefore muſt adhere but looſely, as being ſuperabundant.

Every day's experience ſhews that vitriolated vegetable alkali and gypſum are more copiouſly diſſolved, if the water be ſharpened by a ſmall portion of vitriolic acid; nay, the nitrous acid has the ſame effect; and in general this holds good of all ſalts hitherto known, excepting only tartarized tartar, and thoſe which agree with it in qualities; for this ſalt, when the proportion of acid is encreaſed, degenerates into tartar, which is far more difficult of ſolution. It would be ſcarce worth while to demonſtrate that alum agrees with the other ſalts in this reſpect, were it not that it has been called in queſtion.—What follows, will, I hope, elucidate that matter ſufficiently (*i*).

(A) I choſe 12 glaſſes of a conical figure, as nearly ſimilar and equal as poſſible; to the firſt, I did not add any vitriolic acid; in the ſecond, I put 4 drops; in the third, 6; and ſo on, as the following table ſhews; where the column marked *number of glaſſes* ſhews the number of drops put into each—(100 drops weigh about 113 grains). This being done, an equal meaſure of a ſolution of alum filtered, was put into each glaſs:—I employed Roman alum, and therefore filtering was neceſſary, to ſeparate the earthy part. The glaſſes were ſet in a place where the thermometer ſtood during the whole experiment (which laſted 25 days) between 6° and 10°: after the 1ſt, 2d, 6th, and 25th days, whatever was found cryſtallized was taken off with a ſilver ſpoon, and dried for 10 hours, upon a bibulous paper folded, and was then weighed. In order to avoid fractions, I expreſs

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(*i*) See the Stockholm Tranſactions, in which I firſt publiſhed theſe experiments.

the weights in docimaſtic pounds, 400 of which are equal to 215 grains.

| Number of glaſſes. | After 1ſt day. | After 2d day. | After 6th day. | After 25th day. | | Sum total. |
|---|---|---|---|---|---|---|
| 0 | 50 | 5 | 3 | 18 | = | 76 lb. |
| 4 | 39 | 13 | 2 | 17 | = | 75 |
| 6 | 38 | 11½ | 2 | 18 | = | 69½ |
| 8 | 30 | 14 | 1½ | 16 | = | 61½ |
| 12 | 30 | 13 | 1 | 17 | = | 61 |
| 16 | 20 | 19 | 1 | 18 | = | 58 |
| 20 | 20 | 16½ | 1 | 20 | = | 57½ |
| 24 | 14 | 22 | 1 | 20 | = | 57 |
| 30 | 14 | 22 | 1 | 20 | = | 57 |
| 40 | 15 | 18½ | 1 | 23 | = | 57½ |
| 50 | 12 | 23 | ½ | 23 | = | 58½ |
| 100 | 16 | 25 | ½ | 24 | = | 65½ |

(B) I repeated the experiment, only making uſe of five glaſſes; into each I put one half the meaſure of filtered ſolution of alum, and the number of drops of the acid indicated in the firſt column beneath: 100 drops now weighed about 92½ grains. The experiment took up 23 days; at the end of which time all the moiſture in the firſt glaſs had evaporated.—The temperature was between 15° and 20°.

| Number of glaſſes. | After 1ſt day. | 7 days. | 12. | 23. | | Total. |
|---|---|---|---|---|---|---|
| 0 | 199 | 30 grs. | 44lb. | 56lb. | = | 329lb. |
| 25 | 190 | 21 | 52 | 64 | = | 327 |
| 50 | 172 | 29 | 53 | 66 | = | 320 |
| 75 | 166 | 17 | 52 | 67 | = | 302 |
| 100 | 163 | 26 | 50 | 58 | = | 297 |

Hence it eaſily appears, that the ſmalleſt addition of acid impedes the cryſtallization. A compariſon of the 3d, 4th, and 5th column, will indeed ſhew many irregularities, which may be exhibited by a curve, by erecting, perpendicular to the axis, ordinates proportioned to the number in each column, and by taking the abſciſſæ proportional to the numbers in the firſt column. Theſe irregularities can hardly depend entirely on the inequality of the cups; but undoubtedly they depend, at leaſt in part, upon the different relative proportions of the alum, water, and acid; beſides, a perfect equality cannot be preſerved in a number of drops: but this does not affect the general concluſion; for if by accident, where the difference is ſmall, 4 ſhould = 6 in weight, this will not happen where the difference is greater, without remarkable negligence.

Beſides, I took as much care as poſſible that the ſolution poured into the laſt glaſs ſhould be as warm as that in the firſt. If any variation happened here, it muſt have ariſen from the latter glaſſes being richer than the former, on account of the contraction of bulk by cooling.

That the evaporation ſhould proceed ſenſibly during the whole time of the proceſs, the broad ſurfaces give reaſon to expect; and all the phenomena demonſtrate that it was ſo. It is otherwiſe in the manufactories (§ VIII. c).

(c) To avoid the exception ariſing from the inequality of the drops, I made the experiment in the following manner:—I diſſolved 215 grains of pure alum in diſtilled water, in a ſmall cucurbit, and evaporated over the fire until the ſurface of the liquor correſponded with two oppoſite marks on the narrow neck, which, according to former experiments, indicated that the warm ſolution was fit for cryſtallization; I therefore poured it out into a glaſs: in the ſame cucurbit, after waſhing it, I again diſſolved and evaporated 215 grains, with the addition of 24 grains and an half of concentrated vitriolic acid. This ſolution was poured out into a glaſs ſimilar and equal to the former. I repeated the experiment a third time, with no other alteration than the addition of 53 grains of vitriolic acid. The glaſſes were then all ſet cloſe together, in a place the temperature of which was 10°. After 56 hours, I collected the cryſtals, and left them untouched for 12 hours, upon bibulous paper, many times doubled. At the expiration of that time I found the weight of cryſtals obtained from the firſt cup to be 155¾, from the ſecond 130, and from the third only 100¼.

(D) The laſt objection is, that the vitriolic acid attracts water very ſtrongly; and therefore no other way impedes cryſtallization, than by taking away the water neceſſary for the ſolution. The queſtion is not at preſent in what manner the vitriolic acid acts; and therefore, without giving up my theſis, I might allow this conjecture to be right. But I took that opportunity of examining into its truth: for this purpoſe, I provided two equal and ſimilar bottles, A and B; into each I put eight ounces of diſtilled water, and into B only I put 50¼ grains of vitriolic acid: I afterwards added to each equal portions of powdered alum, and immediately cloſed them both well. As long as none remained undiſſolved, I continued to add more alum, and did not ceaſe, until a portion remained for ſome days, which the liquor was incapable of diſſolving. Equal portions of the ſalt were always more quickly diſſolved in B than in A. The water in A diſſolved only 339½; that in B 373, and 80¼ more upon the further addition of 134½ of vitriolic acid.

Since, then, the ſolution is as it were in the inverſe ratio of cryſtallization; and as no difference in evaporation could take place, the bottles being nearly full, placed near one another, and well ſtopped; I conclude, that the acid of itſelf encreaſes the ſolubility, or, which is the ſame thing, impedes the cryſtallization.

## § xi.

After having ſhewn, by many experiments, that the cryſtallization is impeded by the ſuperabundant acid, the queſtion now is concerning the moſt commodious method of detaching that ſuperfluity.

(A) Alkaline ſubſtances, ſaline or earthy, are no doubt capable of ſuppreſſing it, but theſe ſuperadd a ſalt of another kind. It ſometimes happens, that alum does not yield firm cryſtals, a fact firſt obſerved by M. Margraaf, who alſo ſhewed, that this inconvenience aroſe from a ſmall quantity of vegetable alkali. I know that, without any addition, complete cryſtals may be obtained; but for the moſt part, unleſs the evaporation be carried on extremely ſlow, the great portion which remains after the depoſition of a few perfect cryſtals is nothing but a ſaline magma. It is remarkable that this impediment to cryſtallization is equally well removed by volatile alkali, but not by mineral alkali, or by lime (and this points out the reſemblance between vegetable and volatile alkali, as alſo between mineral alkali and lime, a reſemblance which we ſhall ſee elſewhere (*k*): not only the

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(*k*) Diſſertation on Platina, vol. ii.

the common, but even the Roman alum, when precipitated by a volatile alkali, yields a liquor which not only contains an ammoniacal ſalt, but frequently a vitriolated vegetable alkali; which latter may be had alone, the former being ſeparated by ſublimation. The preſence of this alkali is owing either to the clay itſelf being adulterated with the reſiduum of putrified vegetables, or from aſhes, either added on purpoſe, or accidentally mixed, during the calcination and roaſting. In the mean time, it is certain that alum and vitriolated vegetable alkali eaſily unite, and thus a triple ſalt is formed: the alum, deprived of this addition, is unfit for making the pyrophyrus, which may be eaſily tried; for the aluminous magma which refuſes to cryſtallize diſtinctly, yields, when treated in the uſual way, not a particle of pyrophyrus; whereas it yields an excellent one, upon the addition (*l*) of a ſmall quantity of vegetable alkali (*m*).

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(*l*) Vid. Scheele on Fire.

(*m*) It is difficult to imagine how this alkali contributes to the production of pyrophorus, more eſpecially ſince M. Prouſt has ſhewn, that it may be obtained without alum, and even without vitriolic acid; that the reſiduum of ſaccharum ſaturni, after diſtillation, cryſtals of verdigreaſe, and ſeveral other metallic ſalts, are true pyrophori; in a word, that almoſt every ſubſtance which leaves, after its decompoſition, a coally matter, ſimply divided by an earth, or a metallic calx, has the ſame property (*Journ. Phyſ.* 1778, *Suppl.* p. 432). Morveau. See Prieſtly, vol. iii. and iv. Appendix.

Theſe circumſtances ſuggeſt a ſuſpicion, that vegetable alkali is neceſſary for the perfection of alum; and that therefore all perfect alum ſhould be conſidered as a triple ſalt; but this conjecture is not well founded, as the ſame perfection may be obtained by the volatile alkali, and a ſpontaneous evaporation. However, I do not ſuppoſe the addition of vegetable alkali improper, provided it be pure; for if impure it is more noxious than uſeful. The whole of the ſuperabundant acid, however, muſt by no means be ſaturated with alkali, as the alum would in that caſe be too much mixed with a foreign ſalt, and the operation be rendered expenſive, without gaining any advantage.—Urine ought to be avoided, partly on account of the heterogeneous matters which it contains, partly on account of the volatile alkali, which communicates to alum properties that render it unfit for the purpoſes of dying.

(B) But as a pure clay conſtitutes the baſis of alum, the ſuperabundant acid cannot by any other means be more conveniently repreſſed than by this earth: which, at the ſame time that it prevents the noxious ſuperabundance, increaſes the quantity of alum. I am very much ſurpriſed that ſo excellent and obvious a remedy has never been propoſed by any perſon, at leaſt ſo far as I know.

In order to aſcertain what was to be expected from this, I inſtituted ſeveral experiments, by which the truth of the above aſſertion was ſufficiently evinced. It will be ſufficient to relate two: —I employed a magiſtral lixivium, in which the the exceſs of acid was nearly in quantity as deſcribed (§ IX. C.); to a kanne of this I added two drachms of pure clay, reduced to a fine powder, and moiſtened with a few drops of water: I then applied the heat of ebullition, which I continued for ten minutes; when all was cold I ſeparated the clay that remained, and upon waſhing and drying I found that 25; grains were diſſolved; which indicates an increaſe of alum of 141 grains (§ III. B.). At another time I employed gentle boiling for half an hour, by which 75 grains were taken up, ſo that 416 grains of alum were produced; hence a ſingle boiler would produce 1,400 ounces.

I entertain no doubt, therefore, but that the addition of clay is extremely uſeful; and this ſhould be done at the very firſt, when the lixivium is put into the boiler; a clay free from lime is neceſſary, as this laſt would produce gypſum; it muſt alſo be free from any thing vitriolic In general the quantity is to be regulated by the quantity of ſuperabundant acid; and we muſt conſider that the earth of alum frequently conſtitutes only one fourth of argillaceous earth. A few trials will, in the preſent caſe, be ſufficient to direct us.

## § XII.

Many circumſtances relating to the method of obtaining alum pure have been mentioned in the foregoing ſection, where we treated of repreſſing the ſuperabundant acid.

Alum, as it is commonly made, although depurated by a ſecond cryſtallization, yet is almoſt always found contaminated with dephlogiſticated vitriol; hence it grows yellow by age, and when diſſolved in water depoſits ochre. This, in many of the arts, is equally uſeful with pure alum; it is even ſo in dying, when dark colours only are wanted, which frequently require green vitriol: but when the more lively colours are ſought, every thing martial muſt be avoided, as it always obſcures them more or leſs. In ſuch caſes the Roman alum is employed: it is therefore required to diſcover a method by which the common alum may be ſo depurated as to equal the Roman in goodneſs. The common ore, indeed, always contains more or leſs martial, which even actually enters the lixivium; notwithſtanding this, however, we muſt not deſpair (*i*).

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(*i*) "The preference given by dyers to Roman alum does not appear to me a ſufficient reaſon for concluding that it is not coloured by iron. It is certain, that the red ſelenite above mentioned does not any more ſhew ſigns of martial earth, in conſequence of the addition of tincture of galls, and Pruſſian alkali, although it contains iron enough to be reduced." Morveau.

(A) Alum, made without the addition of the magiſtral lixivium, both as to purity and efficacy, rivals the Roman alum, and often excels it. The crude lixivium, indeed, contains vitriol, but in ſuch quantity that it is entirely ſeparated by the ſecond cryſtallization: for the alum made in this way does not ſhew the ſmalleſt ſign of iron, either with tincture of galls or phlogiſticated alkali; beſides, by the ſecond cryſtallization all the earthy parts are ſeparated, which earthy parts always adhere to the Roman. By my advice, this method was purſued in two of our manufactories, and an alum prepared ſuperior to the Roman.

The reaſon is plain, for the noxious heterogeneous matters at firſt remain in the magiſtral lixivium; now, as two thirds of this continually enter the following decoctions, theſe matters are continually accumulating, inſomuch that the alum being in the firſt cryſtallization overwhelmed with theſe, can be but imperfectly freed in the ſecond; nay, a third or a fourth are ſometimes neceſſary, to form as good alum as is had without the addition of the magiſtral lixivium by means of two. How abſurd this continual addition of the magiſtral lixivium is, will ſufficiently appear from its nature, and will be demonſtrated more at large in the following paragraph.

(B) If the lixivium abounds with dephlogiſticated vitriol, (which is eaſily diſcovered by the red colour, and the continual depoſition of ochre) this is deſtroyed by the addition of clay: and let not this be thought contradictory to the general laws of attraction. It is indeed true that iron, put into a ſolution of alum, is diſſolved, and precipitates the earthy baſe of the alum: as alſo that, when vitriol and alum are both in the ſame ſolution, if an alkali be added gradually, and without agitation, the white argillaceous earth will be firſt precipitated, and afterwards the greeniſh martial earth. But this is only true of iron in a metallic ſtate, or but little dephlogiſticated; for if the inflammable principle be any further diminiſhed, the efficacy of attraction is thereby ſo much weakened, that the iron, being now calcined, will yield the vitriolic acid to pure clay. The truth of this aſſertion may be proved many different ways: thus, let a portion of alum be diſſolved in a lixivium of highly dephlogiſticated vitriol; let an alkali be then added, and ochre will be precipitated firſt, and not until after it clay; beſides, if clay be added to ſuch a lixivium, and boiled, alum is formed; and, provided there be a ſufficient quantity of clay, the whole of the vitriolic ſalt will be deſtroyed.

Thoſe who are fond of wonderful tranſmutations, and accordingly ſee them in every thing, will in this inſtance rather ſay, that the martial is commuted into an argillaceous earth: they add, to finiſh the demonſtration, that the ſalt elixated from colcothar of vitriol not only (like alum) refuſes to cryſtallize without the addition of a little vegetable alkali, but alſo yields tranſparent cryſtals, which reſemble alum in the aſtringency of their taſte.

Theſe phænomena are true, but the concluſion deduced from them is erroneous. The more frequently vitriol of Mars is diſſolved, and again cryſtallized, the more it is deprived of its green colour, and at length it totally loſes it; hence the watery colour of the ſalt obtained from colcothar: the taſte is aſtringent, like that of vitriol, but with ſome ſmall difference, the metallic baſe being here deprived very much of its phlogiſton: beſides, that the ſalt got from colcothar moſt commonly does not contain a particle of alum, there is no doubt; for every common vitriol owes its origin to pyrites, which is rarely without ſome clay; therefore we have no occaſion for a metamorphoſis to account for the production of alum: but that vitriol, which is formed of iron and pure vitriolic acid, never ſhews the ſmalleſt veſtige of alum; and the colcothar ſalt obtained from ſuch vitriol, upon the addition of a fixed alkali, depoſits nothing but an ochre; but with a phlogiſticated alkali the whole baſe is converted into a Pruſſian blue.

From all this it evidently follows, that an aluminous lixivium, which is only contaminated by dephlogiſticated vitriol, may be at once enriched and depurated, by the addition of pure clay free from vitriolic matters.

(c) A lixivium containing perfect vitriol cannot be freed from it to any purpoſe, either by clay or alkali; for the former effects no decompoſition, unleſs in ſo far as the vitriol is dephlogiſticated by long boiling: the latter, although it can deſtroy all the vitriol, yet it cannot effect this, ſo long as any alum remains, which yields its acid more readily.

## § XIII.

In applying the magiſtral lixivium to uſe, we muſt take notice of many varieties, the chief of which depend upon the admixture of a vitriolic ſalt, as this renders the alum unfit for certain purpoſes; and, if the quantity be large, renders it unapt to cryſtallize. However, we muſt alſo take into the account vitriolated magneſia, which not unfrequently is found mixed with it.

(A) A magiſtral lixivium containing alum alone, is ſcarcely found any where, except at Tolfa. Mr Fougeroux de Bondaroi obſerves, that this, expoſed very much to the air in broad ſhallow veſſels, by degrees, though ſlowly, yields genuine alum, in the ſame way as clay artificially combined with vitriolic acid, which, though in the uſual way it only affords incoherent cryſtals, affords very complete ones by a ſlow ſpontaneous exſiccation. I have not yet been able to diſcover the reaſon of this phænomenon; but in the foregoing pages I have mentioned, that this diſpoſition to cryſtallize may be induced by the addition of a little vegetable or volatile alkali, but not by the mineral alkali, or lime (§ XI. A).

In the magiſtral lixivia there ſometimes occurs a ſpecies of fat, as is judged not ſo much from its viſcid appearance (which may be occaſioned by the quantity of the matters diſſolved) but from its nature and properties; for a ſaturated ſolution of alum, in the ſame manner as other ſalts, if kept long, or boiled in a glaſs veſſel, communicates to the glaſs the property of repelling water, as if it had been ſmeared with oil, and wiped with a cloth. So long, therefore, as we know no other bodies but oils which communicate this property, we muſt conclude, that ſomething at leaſt analogous to oil is in the lixivium.

(B) The lixivium containing perfect vitriol, ſo long as it is rich in alum, may be employed, as it uſually is, but only for the preparation of common alum; whereas, if the vitriolic ſalt abounds, it muſt either be cryſtallized into a vitriol, or elſe be ſo deſtroyed as to produce alum, which may be done in the following way:—let the lixivium be reduced to a tenacious maſs with clay, and formed into cakes, and theſe be expoſed in an houſe to the open air; by theſe means the phlogiſton, which is powerfully attracted by pure air, is by degrees ſeparated from the iron, while the acid, by its ſtronger attraction, takes up the clay;

the calcination is accelerated by fire, but it muſt be cautiouſly employed, leſt the acid ſhould be expelled: the lixivium is thus treated to much more advantage than by continued boiling, particularly when it contains but little alum (*k*), as is the caſe in our manufactories about the end of the ſummer, as the noxious foreign matters are increaſed on every boiling.

(C) The lixivium, containing dephlogiſticated vitriol, may be advantageouſly treated, by adding clay during the boiling: the reaſon has been already explained (§ X. B), ſo that we need not dwell upon it here.

(D) The lixivium containing perfect vitriol, and vitriolated magneſia, is the moſt common in our manufactories; this may be employed in the ordinary way for the preparation of common alum, in the beginning of ſummer, and ſo long as the heterogeneous matters have not accumulated too much; but when that takes place, it is proper to ſeparate the vitriolated magneſia; for this purpoſe it is neceſſary to decompoſe the vitriol, and alſo the alum, for they cannot be ſeparated by cryſtallization (§ IX.); this is beſt done by a calcareous powder, which muſt be unburnt, as, if burnt, it would alſo decompoſe the vitriolated magneſia: this powder is to be added by degrees, leſt the effervеſcence ſhould occaſion the maſs to ſwell over

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(*k*) Vid. Monnet ſur l'Alunation.

the ſides of the veſſel: a juſt proportion removes the ſalts, by the aſſiſtance of agitation and heat; phlogiſticated alkali will readily ſhew whether there is any thing martial remaining. In the place of the decompoſed ſalts there remains gypſum, but only a very ſmall portion of it remains in the lixivium; for, on account of the deficiency of menſtruum, the greateſt part falls to the bottom along with the ochre and clay. As ſoon as the liquor has ſubſided and grown clear, it muſt be carefully decanted into another veſſel, and evaporated until a drop let fall upon a cold ſubſtance ſhews cryſtals in a few minutes; it is then to be removed from the fire, and, on cooling, it produces vitriolated magneſia.

If in our manufactories all the magiſtral lixivium which is unfit for making alum was treated in this manner, we ſhould undoubtedly obtain as much Epſom ſalt as is conſumed in all Sweden: this ſalt is now imported; whereas, if at the ſame time this and other means were uſed, we might be able to export to all Europe.

It is evident that this lixivium may alſo, by the methods above deſcribed, be employed for the artificial preparation of the matrix of alum.

(E) The magiſtral lixivium has always a ſuperabundance of acid: we found in one kanne nearly five ounces; ſo that in a ſingle boiler there are nearly 250 lb.: but vitriol, when well dephlogiſticated, retains its acid ſo looſely, that it may eaſily be ſeparated by fire. I do not doubt, therefore, but that ſuch a lixivium, if its ſurface be firſt increaſed by pouring over an heap of ſticks, and afterwards collected, might be advantageouſly ſubjected to diſtillation.

(F) Finally, the ochre, which ſeparates either ſpontaneouſly or upon the addition of an alkali, may be made, by various methods of preparing it, to afford various pigments;—it is enough here to throw this out as a hint.

## § XIV.

From what has been ſaid, I believe it will plainly appear, that if the operations were conducted with ſkill and prudence in our manufactories, we ſhould have, at the ordinary expence, alum better in quality, and a larger quantity. I flatter myſelf, that in foregoing ſections I have pointed out the means of obtaining this end. As to the forms of furnaces, and other contrivances for more commodiouſly conducting the operations, I paſs them over, as belonging rather to mechanics than chymiſtry, although theſe two frequently lend one another mutual aſſiſtance.

# DISSERTATION X.

# OF

# ANTIMONIATED TARTAR.

## § 1. *Medicines ſhould be preſcribed in ſuch a Way, that each ſhall always poſſeſs the ſame Virtues.*

IN preſcribing medicines, or in compoſing diſpenſatories, nothing is more neceſſary than that both the materials and method of preparation be ſo choſen as to be exactly alike in all caſes and ſituations: for if the officinal preparations be not directed to be made in ſuch a manner, that they can never, under the ſame name, poſſeſs different virtues and properties; or if the proceſs be ſo ordered, that, notwithſtanding all poſſible care in the repetition of it, it cannot to a certainty be performed in the ſame way, it plainly appears, that medicines of very different qualities may be produced by the ſame formula, and that not only in different ſhops, but in one and the ſame. The danger hence ariſing is indeed but ſmall, when the leſs powerful preparations only are ſubject to this inconvenience; but from what follows, it will appear, that this is often the caſe with thoſe which are poſſeſſed of conſiderable activity.

For example, let us ſuppoſe an emetic, or a purgative made by the ſame formula, and, nevertheleſs, that the medicine does not always produce the effect deſired, that it at one time has little or no effect, at another acts moſt violently; in this caſe, beyond doubt, the life of the patient is endangered, the credit of the phyſician injured, and preparations which, if rightly adjuſted, would be of the moſt material advantage, fall gradually into diſrepute, and at length into total diſuſe.

All theſe inconveniencies are found to take place in many officinal preparations, particularly thoſe of metals, many of which, though known by the ſame name, are in degree of efficacy entirely unlike.

## § 11. *Antimonial Emetics.*

From the moſt remote times antimonials were known to poſſeſs an emetic quality: this property they exert only when diſſolved; but in general they can undergo ſolution within the body as well as without; for, in the primæ viæ, there are ſometimes humours endowed with the property of diſſolving this ſemi-metal; and on this account antimonials were formerly given in the form of powder. But as it is plainly impoſſible for us to determine, *a priori*, either the quantity or quality of this menſtruum, it follows, that from variation in it, either of quantity or quality, the doſe muſt be uncertain, and the effect extremely dubious. Examples are to be met with, of ſome perſons who could ſwallow conſiderable quantities of the regulus, without any inconvenience, which would be highly dangerous to perſons who are ſubject to acidity. At preſent, the mercurius vitæ, the hepar antimonii, and pulverized glaſs of antimony, are much in uſe, becauſe theſe ſubſtances contain the regulus, reduced by ſolution to a ſaline nature; they therefore may be given with much more ſafety, and, being always the ſame, act more powerfully and certainly. Tartar has been almoſt always in uſe, as a ſolvent for this metal; and the ſalt ariſing from this compoſition has been called *tartar emetic* (*a*), from its operation; and *ſtibiated tartar*, from its compoſition.

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(*a*) Mynſicht firſt introduced this preparation in 1631. He employed the crocus metallorum; Zwelſer, the glaſs of antimony; and Lemery, the hepar.

I prefer, however, the name of antimoniated tartar, as antimony is at preſent a more popular name for this mineral than ſtibium: and this preparation of antimony I deſign to examine in the following pages.

### § 111. *Different Methods of Preparation.*

Upon turning over the moſt celebrated diſpenſatories, we find a wonderful difference in the methods of preparing this ſalt; all, except the old diſpenſatory of Stockholm, which mixes with it a lixivious ſalt, preſcribe the cryſtals, or cream of tartar, as the menſtruum; but differ with reſpect to the matter to be diſſolved.

The crocus metallorum is directed by the new Vienna diſpenſatory (*b*), by the new Utrecht (*c*), the Wirtemburg (*d*), the Edinburgh (*e*), Boruſſo Brandenburg (*f*), the London (*g*), and ſome others; but the Edinburgh and the Brandenburg admit the uſe of the glaſs of antimony, which is the baſis employed by the old Stockholm (*h*) and the Ratiſbon (*i*); but the Paris diſpenſatory (*k*) orders it with an equal part of the hepar, not freed from the ſcoriæ. The Pharm. Bateana (*l*) em-

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(*b*) An. Dom. 1734.

(*c*) 1749.

(*d*) 1750.

(*e*) 1756.

(*f*) 1758.

(*g*) 1758.

(*h*) 1686.

(*i*) 1727.

(*k*) 1738.

(*l*) 1688.

ploys the flowers of antimony. As to the proportions, the Ratiſbon, Vienna, Utrecht, Wirtemburg, London, and Brandenburg, employ an equal weight (*m*) of tartar and of the metallic matter; the Edinburgh and Paris double that quantity: there is alſo a difference with reſpect to the quantity of water. In the Vienna and Edinburgh diſpenſatories, 12 parts of water are ordered to one of tartar; 6 in the Wirtemberg; and in the reſt, ſo much as is ſufficient for ſolution. The mixture, being digeſted for a day or two, is boiled until the tartar is completely diſſolved, according to the inſtructions of the Brandenburg diſpenſatory, and moſt others; but the Paris directs, in expreſs words, 12 hours, the Edinburgh 10, and the London half an hour. After filtration, the Ratiſbon and London require cryſtallization; the reſt evaporation to dryneſs. In the old Stockholm diſpenſatory, one ounce of glaſs of antimony is deflagrated with two drachms of crude nitre; one drachm of alkali of tartar, and nine ounces of pure water, are then added; the whole is boiled to dryneſs in an iron pot, the maſs reduced to powder; warm water is poured on; it is filtered; and, being evaporated to dryneſs, is ſtrongly heated on an unburned brick.

The above will be ſufficient to ſhew the diſagreement of the diſpenſatories: indeed, to com-

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(*m*) Vid. Diſpenſ.

pare the differences minutely, would exceed the bounds of ſuch a Treatiſe as this. We may, however, obſerve another method formerly in uſe, for the purpoſe of exciting vomiting, which is in itſelf ſufficiently commodious, if it were ſufficiently exact:—wine was ſet to ſtand for a night, in a cup made of regulus of antimony and tin; or elſe balls of this metal, which were called perpetual pills, were ſteeped in wine for a certain number of hours. What judgement is to be formed of theſe contrivances, the following experiments will ſhew: when we conſider the diſagreements above mentioned, and others that might be adduced, we ſhall ceaſe to wonder at the uncertain effect of emetic tartar.

Upon accurate examination, we ſhall ſee that the weaker of theſe preparations contains ſcarcely five hundredths of the metal, while the ſtronger have upwards of 0,24. Hence, then, appears the neceſſity of determining the baſis and the menſtruum in ſuch a manner, by accurate experiment, that this medicine may always poſſeſs the ſame properties, and the ſame degree of ſtrength.

### § IV. *The Baſe to be choſen.*

The hepar, the crocus metallorum, and the glaſs of antimony, are the ſubſtances generally made uſe of as the baſis of tartar emetic. We muſt firſt inquire, whether theſe three, prepared according to the uſual formula, actually contain the ſame quantity of phlogiſton; for, according to the variation of that principle, a greater or ſmaller portion of the metallic regulus will be diſſolved in the ſame quantity of menſtruum; and of courſe the emetic power will vary. That hepar which is prepared with a larger proportion of nitre, neceſſarily loſes more of its phlogiſton than that in the preparation of which leſs nitre has been employed; and even although an equal quantity of nitre and antimony be (as is uſually the caſe) employed for this purpoſe, it ſtill depends upon other circumſtances, whether the reguline part be acted upon at all, and in what degree. The deflagration is performed, either by throwing the nitre and antimony into a hot crucible, or by ſetting fire to the mixture in a cold mortar: in the former caſe, the ſulphur is more quickly deſtroyed, and flies off; ſo that the metal is of courſe more completely deprived of its phlogiſton, than in the latter, where no fuſion takes place; and there is no external operation of fire: hence the hepar made in the latter way is red, that produced by the former method rather yellow. But though the proceſs were univerſally conducted in a crucible, it is impoſſible at all times to apply the very ſame degree of fire; nor can the difference of degrees be poſſibly aſcertained: ſo that, from this circumſtance alone, the products muſt differ eſſentially; add to which, that the nitre and crude antimony cannot be mixed together ſo evenly, but that in one part the nitre will prevail, in another the antimony; and hence alſo a variation in the product muſt neceſſarily take place;—and the natural conſequence of this variation is, that the regulus is ſcarce ever acted upon twice in exactly the ſame manner.

All the above-mentioned differences ariſing in the preparation of hepar, affect in the very ſame manner the production of the crocus metallorum; the latter being no other than the reſiduum of the former, inſoluble in water. Beſides, another variation in this preparation may ariſe from the difference of accuracy in waſhing; for, on this account, more or leſs remains, which, by encreaſing the weight, and abſorbing the acid, not only weakens the ſtrength of the menſtruum, but prevents the ſame weight of it from containing always the ſame quantity of antimony.

Glaſs of antimony is obtained from the fuſed calx of this metal. Now, as the regulus, the crude antimony, and other preparations, may each be calcined by means of fire; and as all theſe, according to circumſtances, and the nature of the preparation, loſe phlogiſton in different degrees, it follows inevitably, that the glaſſes made of the calx muſt differ much from each other.

But, ſuppoſe the crude antimony always uſed for this purpoſe, as many direct it to be, yet even in this caſe we cannot be ſure that the ſame force of fire has been employed; and as that varies, the calx may ſometimes be ſo far deprived of phlogiſton, as to be vitrified with great difficulty. and ſometimes retain ſo large a portion of the inflammable principle as to reſemble the hepar in fuſion, rather than the glaſs; and between theſe two extremes there are innumerable intermediate degrees. When we conſider every thing attentively, we ſhall ceaſe to wonder at the different degrees of tranſparency, and the different colours of the glaſs.

Hence we may conclude, that neither the hepar, the crocus, nor the glaſs, can ſupply a baſe for emetic tartar, which will be always ſimilar to itſelf; and therefore, that they are to be avoided, if a more proper ſubſtance can be found.

It may perhaps be thought, that the regulus is preferable to thoſe ſubſtances which are moſt in uſe; but even if we were in poſſeſſion of a ſure method of regulating the fire in the preparation of the regulus, ſo that it ſhall always be of the ſame nature; and although we alſo had a ſure and commodious method of meaſuring the ſolvent power of the menſtruum, yet it remains to be determined by experiment, whether antimony, in its reguline ſtate, can communicate an emetic quality to acid liquors.

Boiling vinegar indeed attacks it; but for the acid of tartar, ſee § VI. A. VII. A. Many perſons extol the virtues of wine which has lain in a cup of the regulus, and had the powdered regulus ſteeped in it for 24 hours; but in this inſtance an error may readily conceal the truth: for minute particles of the powdered regulus may, on account of its micaceous texture, be eaſily ſuſpended in the liquor, and therefore may be ſometimes ſwallowed: beſides the regulus when, either by means of too much fire, it is externally deprived of a portion of its phlogiſton, or mixed, either internally or externally, with an hepar, it may communicate to wine an emetic quality, although the reguline part itſelf contributes nothing to it. In order to obtain a deciſive concluſion, the regulus ſhould be often well fuſed with a fixed alkali, and then well waſhed with vinegar; beſides, the wine which is decanted off ſhould be filtered through paper;—this I never had an opportunity of trying more than twice. I ſteeped the regulus, eliquated according to the London diſpenſatory, divided into ſmall pieces, and well waſhed in Rheniſh wine, and kept the bottle cloſed in a moderate heat for ſix days: the wine, after filtration, did not ſhew the ſlighteſt token of an emetic virtue.

Of all the antimonials none deſerve ſo much attention as the powder of Algaroth, which was ſome time ſince thought well adapted to this purpoſe (*n*).—The following experiments will ſerve to ſhew its nature more completely. It is obvious, that if 3 parts of crude antimony, and 4 of corroſive ſublimate, be mixed together, by means of heat, and a double elective attraction, a double exchange will take place; for in the corroſive ſublimate there is calcined mercury, and in the crude antimony the regulus combined with ſulphur: during the operation the antimony yields its phlogiſton to the calcined mercury, which thereby becomes quickſilver, and in its turn yields its marine acid to the antimonial calx. This compound paſſes over into the recipient, under the name of butter of antimony; and if at length the heat be much increaſed, cinnabar is formed, conſiſting of the ſulphur of the crude antimony united with the mercury. We muſt take particular notice that neither the regulus of antimony, nor of any other metal, can be taken up by acids, until it is to a certain degree deprived of its phlogiſton; and that degree is various in various caſes, as I have elſewhere demonſtrated (*o*).

Butter of antimony, dropped into water, is inſtantly decompoſed; the water ſeizes the greater part of the marine acid, and the deſerted metal falls to the bottom in the form of a white pow-

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(*n*) By Macquer.

(*o*) De Attr. Elect.

der: this powder was formerly known by a number of ſingular names, to which it had little claim; but is now generally called powder of Algaroth, in honour of Vittorio Algarotti, an Italian phyſician, who has been very laviſh in praiſe of it.

In this operation the antimony is conſtantly acted upon in the ſame manner by the marine acid, and conſequently always loſes an equal quantity of its phlogiſton, which is a circumſtance very much to our purpoſe. How well ſoever this precipitate be waſhed, tho' with warm water, yet ſtill a ſmall quantity of the acid adheres, as appears from hence, that upon diſtillation a ſmall portion of butter of antimony comes over into the recipient; but the acid admixture may be avoided by ſaturating it gradually with oleum tartari per deliquium; for in this caſe the more minute and white particles fall to the bottom, which can only be had by waſhing with an alkali. This is indeed more ſoluble than the former obtained by water, but ſuppoſes a complete decompoſition, which yet is not always obtained; at leaſt there is in this caſe room for fraud, as this method is more expenſive and more troubleſome.

The precipitate obtained by water, although leſs in quantity, is yet perfectly ſoluble, and therefore I prefer it, as being leſs liable to variation; and we ſhould not, without urgent neceſſity, confide in the fidelity of the operator.

The argentine flowers are juſtly enumerated among the beſt preparations of antimony; but the preparation of theſe, although more difficult, yet forms a leſs certain baſe for emetic tartar than the powder of Algaroth does.

### § V. *The proper Menſtruum.*

From the time that this medicine firſt became known, to the preſent day, tartar has been almoſt every where, and at all times, uſed for the menſtruum (*p*); however, as this ſalt is not a pure acid, but, as chymical analyſis and ſyntheſis ſhew, a ſort of tartarized tartar, with a determinate ſuperabundance of acid, it is to be conſidered that we are not yet certain whether the ſuperabundant acid alone acts, or whether the other ingredients contribute any thing.—I am now to relate the experiments which I made to determine that point.

### § VI. *Power of the Acid of Tartar.*

The firſt trials were made with pure acid (*q*) of tartar, of which the ſpecific gravity was to that of diſtilled water, as 1,230 to 1000.

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(*p*) The old Stockholm Pharmacopœia, after Zwelfer, uſes alkali.

(*q*) Retz has deſcribed, in the Stock. Tranſ. the method of obtaining the pure acid of tartar.

(A) The following experiments were made with regulus of antimony, prepared according to the London diſpenſatory, and reduced to a very ſubtile powder. One part of this was boiled for twenty minutes in a phial, with 25 of the above-mentioned acid, then filtered, and ſet in a cold place; it was afterwards further evaporated, when a ſalt concreted in the form of cruſts and furrowed pieces, which in the fire exhibited the ſame properties as cryſtallized tartar, without any viſible antimonial ſmoke. For the better underſtanding of this, we muſt explain the peculiarities of this acid when expoſed to fire upon charcoal, by means of the blow-pipe.

The cryſtals of this acid, which are formed by ſlow evaporation, reſemble thin tranſparent lamellæ, irregularly ſituated in a way which is called cellular by mineralogiſts. As ſoon as the external fluctuating part of the flame reaches the cryſtals, they immediately liquify, and form a maſs pellucid like water; this, when expoſed to the blue conical nucleus of the flame, foams with a loud noiſe; and after the expulſion of the water grows black, ſends forth firſt a ſmoke, then a blue flame, and leaves a quantity of ſpongy ſcoriæ; which diminiſhing more and more by the extremity of heat, at length become entirely white: this reſiduum eaſily diſſolves in acids, and changes the blue juices of vegetables green, in the ſame manner as alkalis do; and this is alſo the caſe with thoſe parts which have not been tried upon the cod. From an attentive conſideration of theſe circumſtances, it appears that this acid has but little effect upon the metal in its reguline ſtate; and the powder collected upon the filter, not being diminiſhed in weight, confirms this opinion.

(B) Hepar of antimony, prepared with an equal quantity of nitre, was put to the proof with the ſame quantity of acid, and in the ſame manner, except that it was only boiled fifteen minutes; but the reſiduum was the very ſame with that deſcribed in the laſt experiment, both with reſpect to cryſtallization and habit with regard to fire, with this ſingle difference, that the reſiduum on the coal is of a reddiſh brown.

(C) One part of crocus metallorum was boiled in ſix of the acid, diluted with water, for the purpoſe of evaporation; this, when filtered, after fourteen days depoſited a ſaline radiated maſs, which gave out ſomewhat of an antimonial fume, when expoſed to the blow-pipe.

(D) One part of glaſs of antimony boiled for 30 minutes with 25 parts of acid, filtered and evaporated, ſeparated, on the ſurface of the liquor in the veſſel, ſmall cryſtalline grains; but all the reſt grew gradually hard, and formed a gelatinous maſs much reſembling cherry-tree gum.

This, when expoſed to the fire, exhibited, beſides the phænomena of acid of tartar, not only an intenſe antimonial ſmoke, but ſeveral metallic grains. The gelatinous matter, and the cryſtalline, poſſeſſed the ſame properties.

(E) One part of diaphoretic antimony, boiled 30 minutes with 25 of acid, and treated as the above ſolutions, yielded at length a white ſaline matter, which, expoſed to flame, ſends forth a little antimonial fume; and the reſiduum is of a browniſh colour.

(F) One part of materia perlata, boiled 15 minutes with 30 parts of acid, yielded a ſaline cruſt, which, expoſed to heat, produced an antimonial fume, and a yellowiſh brown porous ſubſtance.

(G) One part of powder of Algaroth was boiled 30 minutes with 9 parts of acid, and then filtered.

This ſolution, in a digeſting heat, became all gelatinous; but afterwards, in a cold place, by means of an air ſomewhat moiſt, became elegantly ſtreaked by various rays and branches. This gelatinous matter, when expoſed to flame, ſwells violently, and yields a copious antimonial fume, but no metallic grains.

At another time, one part of the ſame powder, precipitated by water, was boiled for an hour with 5 parts of acid; this was diſſolved without any reſiduum; and, on ſlow evaporation, yields irregular cryſtals.

(H) Although in the foregoing ſolutions the acid abounded very much, a good deal of the metal remained undiſſolved, notwithſtanding the boiling: I attempted to ſaturate the powder of Algaroth;—for this purpoſe one part of the powder was boiled two hours with three of acid, when there was no longer any reſiduum; notwithſtanding which, the ſolution retained an acid taſte, and changed the blue juices of vegetables to a red.

Theſe experiments ſhew plainly, that the acid of tartar alone has ſcarce any power in diſſolving this ſemi-metal, ſo long as this laſt poſſeſſes its full proportion of the inflammable principle; but that, in proportion as this principle is diminiſhed, the metal is more fitted for ſolution: this, however, is to be underſtood within certain limits; for although diaphoretic antimony, beyond doubt, contains leſs phlogiſton than the glaſs, yet no conſiderable difference takes place between them with reſpect to ſolubility.

## § VII. *Antimonials diſſolved by tartarized Tartar.*

Tartarized tartar being a neutral ſalt, it does not at firſt appear probable, that it can poſſeſs the property of diſſolving metals and other ſubſtances; yet the following experiments prove that it actually does poſſeſs ſuch a property.

(A) One part of the regulus was boiled 40 minutes with 8 parts of tartarized tartar diſſolved in pure water, and after filtration was ſet in a cool place; a congeries of numerous cryſtals was ſoon formed at the bottom; a piece of this, expoſed to the fire, ſwelled and grew black; its former colour changed to a white; at length the whole maſs was abſorbed by the charcoal, in the ſame manner as happens to crude tartar; and this occurs without the ſlighteſt veſtige of antimony.

(B)*One part of liver of antimony, treated in the ſame manner with tartarized tartar for 30 minutes, produced the ſame phænomena as (A) above.

(C) One part of crocus metallorum boiled two hours with 8 of the ſame ſalt, give tokens of antimony, but very obſcure.

(D) One part of glaſs of antimony, boiled 45 minutes, with 8 of the ſalt, ſeparated, upon evaporation, a ſubſtance compoſed of ſaline ſpiculæ; which, when expoſed to flame, ſwelled much, and yielded many reguline grains.

(E) Diaphoretic antimony, ſubjected in the ſame proportions to the experiment for 35 minutes, exhibited, upon cryſtallization, the ſame phænomena as in (C).

(F) One part of powder of Algaroth, boiled 20 minutes, with 5 of the ſalt, and filtered, yielded cryſtals of two different ſorts, one of which conſiſted of complete tetraeda, and, expoſed to flame, yielded a great number of metallic grains; the other reſembled ſaline ſpiculæ, and ſeemed to be no other than crude tartar; and this being with difficulty ſeparated from the former, ſometimes exhibited marks of antimony.

In another experiment, two parts and a half of tartarized tartar were ſaturated by half an hour's boiling with one of Algaroth, and formed a browniſh red ſolution, which gave a ſlight red tinge to tincture of turnſole, and evaporated to dryneſs, exhibited cryſtalline grains, amounting to three parts and an half.

Hence it is ſufficiently evident, that tartarized tartar can actually diſſolve antimony, although that ſalt had been purpoſely prepared in ſuch a manner that the alkali ſhould prevail, to avoid deception from ſuperabundant acid; beſides, the extraordinary agreement of this with the acid of tartar, appears from hence, that both menſtrua act either not at all, or a little, or much, upon the very ſame preparations.

## § VIII. *Antimonials diſſolved by Cream of Tartar.*

The different ſtrength of the tartareous acid, and of tartarized tartar, being examined, we might in ſome meaſure judge from thence, of the efficacy of tartar which is compoſed of theſe two; but any reaſoning of that kind, not confirmed by experiment, muſt be fallacious.

(A) Two parts of liver of antimony, boiled with one of tartar, after the cryſtals that firſt formed, yielded nothing but an inſipid ſaline gum.

(B) One part of crocus metallorum, boiled with eight of tartar, cemented into a gummy ſubſtance of a browniſh yellow colour.

(C) One part of glaſs of antimony requires at leaſt three of tartar; if it then be diſſolved by boiling, it will yield cryſtals.

(D) Three parts of diaphoretic antimony, made of regulus, united by boiling with two parts of tartar, on evaporation yielded at firſt ſome cryſtals, the reſiduum was a gum, which, when well dried, did not attract moiſture.

(E) Tartar ſcarcely acts upon materia perlata.

(F) Two parts of Algaroth's powder obtained by water, require ſeventy of tartar; if there be more of the menſtruum, and the proper quantity of water, diſſipated by evaporation, the ſuperabundant tartar concretes, containing no more antimony than that which is held by the water of the cryſtals: this combination reddens turnſole; on evaporation it firſt depoſits cryſtals, and then exhibits a clear jelly; a large quantity of water gradually decompoſes it by ſeparating the antimonial calx.

(G) Two parts of the argentine flowers, boiled with one of tartar, yield cryſtals, but no gum: the cryſtals amount to about one fifth of the weight of the antimony.

(H) Bezoar mineral is not diſſolved; but antimony, diſſolved in a proper aqua regia, and precipitated by fixed alkali, is readily acted upon, and forms cryſtals.

In general, to expedite the ſolution of antimonials, we may uſe partly a fixed alkali, and partly borax.

Argentine flowers fuſed with one half of mineral alkali, run together into a yellow maſs, covered with a green cruſt: three parts of this, reduced to powder, are diſſolved by one of tartar, and the whole maſs becomes gummy.

If one part of tartar be added to one half of ſedative ſalt, three parts of this combination take up one of glaſs of antimony, and form a gum, which, being carefully dried, ſplits into a yellow powder, which is ſaid to excel common emetic tartar, both in virtue and ſolubility: but tartar is not by this artifice rendered more capable of diſſolving either regulus, crude antimony, or argentine flowers, than the tartar alone is.

Borax firſt calcined, and melted with an equal quantity of crocus metallorum, forms a maſs of an hepatic colour, five parts of which, mixed with eight of tartar, diſſolved in water, inſtantly generate a colour like that of kermes mineral, and leave no more than two parts undiſſolved, which alſo reſemble the kermes: by evaporation we get a red gummy ſalt.

Tartarized borax attacks crude antimony, forming a tranſparent gummy ſalt of an amber colour, one part of which unites with eight parts of tartar, and holds them diſſolved.

## § IX. *Preparation of an antimonial Emetic, which may be depended upon.*

The foregoing experiments furniſh us with two methods of preparing an emetic of determined efficacy.

Let powder of Algaroth be uſed as the baſis, as it always contains an equal quantity of phlogiſton, which is of great conſequence (§ v.); and let that ſeparated by water be choſen, as it is more certain than that which is obtained by means of alkali (§ IV.) The preſence of marine acid is of no conſequence, provided the quantity be always the ſame;—and let the menſtruum be either cream of tartar or tartariſed tartar: either of the ſalts, thus prepared, will afford an antimonial medicine for the ſhops, of a conſtant and determined degree of efficacy; but as they differ in their own nature, and in the quantity of matter which they take up, their effects muſt differ, at leaſt in degree. I here only mean to inveſtigate the method of preparing medicines which ſhall always poſſeſs the ſame degree of power; and this end is obtained by both theſe operations. It belongs to the practitioner to determine the uſe of theſe, and to diſcover whether there be ſo great a difference between them, that it is neceſſary to be provided with both; or whether one of them may not anſwer the purpoſe, by varying the doſe. In the mean time, I ſubjoin the method of properly preparing the two; and firſt of

*Antimoniated tartar*:—let five ounces of cream of tartar, reduced to powder, and two drachms and an half of powder of Algaroth, precipitated by warm water, waſhed, and dried, be gently boiled in a glaſs veſſel for half an hour, in half a kanne of water; this being done, there generally remains a ſmall quantity of a blackiſh mercurial powder. I do not ſaturate the tartar completely, as, in that caſe, ſome of the ſolution turns to a gelatinous matter, and the ſalt reſulting, being long ſuſpended in the water, is more eaſily decompoſed, which occaſions conſiderable inconvenience in practice (§ VIII. F.): beſides, the weight of a weaker medicine being greater, its quantity may be aſcertained with more accuracy; and it may be taken at different times, without any danger: let the filtered ſolution be evaporated in an open veſſel (not metallic) till a pellicle appears; let it then be kept in a digeſting heat till cryſtals form, which muſt be taken away by degrees, and dried on moiſtened bibulous paper;—all the clear cryſtals are equal in weight to the tartar employed: the more purely ſaline cruſts adhering to the ſides of the veſſel, amounting to

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about half an ounce, are to be well waſhed off with cold water, and kept by themſelves—the laſt red and thick lixivium muſt be thrown away.

*Tartariſed tartar antimoniated:*—let ten ounces of tartarized tartar, and three drachms of Algaroth's powder, prepared as in the laſt proceſs, be boiled in a glaſs veſſel for half an hour, with one-fourth of a kanne of water: let the ſolution be filtered, evaporate the browniſh red lixivium till a pellicle appears, expoſe it then to a digeſting heat, and cryſtals will ſeparate by degrees; theſe muſt be dried upon wet bibulous paper:—when collected they only equal half the weight of the menſtruum; the ſaline cruſts, which may be purified by waſhing, ſcarcely exceed one tenth of the tartarized tartar—the reſt, together with the dark red lixivium, ſhould be thrown away.

## § x. *Properties of antimoniated Tartar.*

The emetic ſalt, prepared after the manner now deſcribed (unleſs the natural coaleſcence of the particles be ſomehow interrupted) is of an octaedral figure, the pyramids ſomewhat more elongated than thoſe of alum; the cryſtals are colourleſs as water, and either wholly, or for the moſt part, tranſparent: the antimony conſtitutes about a third of their weight; they neither crack in the air, nor attract moiſture; but, when old, aſſume an opake whiteneſs: expoſed to flame with the blow-pipe, they decrepitate, burn, emit an antimonial fume, and leave upon the coal ſome metallic grains.

In a moderate heat (15°) diſtilled water diſſolves about $\frac{1}{80}$ its own weight, or nearly three grains, in half an ounce; and that without any alteration, either in colour or clearneſs. Tincture of turnſole is ſcarcely reddened by the ſolution; alkalis, whether fixed or volatile, cauſtic or mild, precipitate it; the ſubtile ſnowy powder which ſeparates adheres very ſtrongly to the glaſs veſſels in which the operation is performed.

In the firſt lixivium (§ IX.) a remarkable difference is obſerved with reſpect to this precipitant; for if it be entirely pure or cauſtic, a white, ſubtile, and very ſpongy powder is ſeparated, which ſubſiding, remains unchanged; but if the alkali be mild, after a few hours the precipitate begins to concrete in the form of radii diverging from different points, reſembling thoſe figures by which ſculptors imitate the ſun: but if the ſolution containing thoſe radiating maſſes be expoſed to an heat of 30°, within a quarter of an hour the figures diſappear, and nothing remains but a ſhapeleſs powder.

That which is precipitated by common fixed alkali after waſhing, being expoſed to flame, betrays ſcarcely any antimony: it leaves a white ſpongy maſs which is totally ſoluble in marine acid, but is ſo far from being diſſolved by vitriolic acid, that, by that acid, it is precipitated from the marine.

A like precipitate is obtained by means of common volatile alkali: but that which is obtained by cauſtic volatile alkali does not exhibit theſe figures; gives out ſcarce any ſmoke when expoſed to flame; and forms an aſh-coloured, fuſible, but fixed glaſs: lime-water alſo precipitates it, but the precipitate is again diſſolved, upon agitation, unleſs a ſufficient quantity of lime-water had been added at firſt;—in this precipitation too the figures appear.

By concentrated vitriolic acid a large quantity of white matter is thrown down, which again diſappears on agitation; if collected, waſhed, and expoſed to flame, it firſt grows brown, and concretes into little maſſes, which afterwards give out an antimonial fume, and are conſumed.

Hepar ſulphuris, dropped into the ſaline ſolution, produces a ſulphur auratum.

The reddiſh yellow colour of this lixivium depends upon iron, as is eaſily ſhewn by phlogiſticated alkali, which immediately generates Pruſſian blue.

## § XI. *Properties of tartarized Tartar antimoniated.*

Tartarized tartar, ſtibiated, forms rarely tetraedral, but generally octaedral cryſtals, if ſuffered to cryſtallize freely; of theſe ſome are pellucid, and void of all colour, others have a little opake whiteneſs; the habits of the cryſtals, both in the air and fire, are the ſame with thoſe of the antimoniated tartar: the metal forms about one-fifth of their weight. Diſtilled water, in a moderate heat, takes up nearly $\frac{1}{40}$ its own weight, that is five grains in half an ounce, and ſtill retains its colour and clearneſs; it ſhews ſome faint ſigns of a ſuperabundant acid; the alkalis and vitriolic acid produce the ſame phenomena as we deſcribed in the former ſection; with this difference, that they are produced more ſparingly and ſlowly, and that the figures there mentioned do not in this caſe occur.

The ſolution of the firſt boiling is of a browniſh red, and the magiſtral lixivium ſtill more ſo: for experiment ſake, a little diſtilled pure vinegar was poured in, and afterwards a ſingle drop of phlogiſticated lixivium, and in an inſtant the blue colour appeared: the iron then, in this caſe, is preſent without an acid; for, to decompoſe the phlogiſticated alkali, a double elective attraction is required. Many of the laſt lixivia, which are red, and do not readily form cryſtals, doubtleſs owe their properties to dephlogiſticated iron.

Whence, in the preſent caſe, this metal can come, is not at preſent very clear: the aſhes are indeed boiled to dryneſs in an iron pot; but the cream of tartar is purified in braſs veſſels: beſides, the white alkali of tartar, when boiled in a glaſs veſſel with powder of Algaroth, gave alſo a browniſh red-coloured tinge.

# DISSERTATION XI.

## OF

## MAGNESIA.

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### § 1. *Brief Hiſtory of Magneſia.*

AT the beginning of the preſent century, a certain canon regular ſold, at Rome, a ſort of powder, under the title of magneſia alba, or Count Palma's powder, which he aſſerted to be a panacea: but the preparation of it was ſolicitouſly concealed as a profound ſecret, until Mich. Bernh. Valentini, in the year 1707 (*a*), diſcloſed the method of preparing it, by calcination, from the laſt lixivium of nitre. Two years after, Joh. Hadr.

(*a*) In a diſſertation printed at Gieſſa. In his *Praxis Medica*, he calls this earth the *laxativum polychreſtum*.

Slevoght (*b*) taught another and more eaſy method of procuring it, by precipitation. After this, in 1717, Lanciſi (*c*) wrote upon this ſubject; as alſo did Fred. Hoffman (*d*), and other moderns. From that time the uſe of this powder has very much increaſed, and it is now introduced into moſt diſpenſatories.

Many conſidered this powder as calcareous earth, as they were not acquainted with any other which effervefced with acids, and, above all, becauſe they neglected all further examination.—However, F. Hoffman obſerved, that it differed from the earth prepared from crabs eyes, ſhells of oyſters, and eggs, in this particular, that all theſe, united with vitriolic acid, afford an inſipid ſalt; whereas magneſia produces one intenſely bitter. At length the nature and properties of magneſia were completely elucidated by two of the moſt celebrated chymiſts of the preſent age; I mean Dr Black, of Edinburgh, who publiſhed his experiments in 1755 (*e*), and the Principal of the academy at Berlin, A. S. Margraaf, who publiſhed his in 1759, *as it ſhould ſeem*, entirely ignorant of Dr Black's Eſſays (*f*). Both theſe gentlemen have examined the nature of this earth with the

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(*b* In a diſſertation printed at Jena, 1709.

(*c*) Annot. in Mercati Metalloth.

(*d*) Obſ. Phyſico-chem.

(*e*) Edinburgh Eſſays.

(*f*) Mem. Berlin.

utmoſt accuracy and diligence; and have moſt evidently ſhewn, that it differs altogether from lime: but, contented with diſcovering its properties and diſtinguiſhing characteriſtics, they paſs over its geneſis, as not being yet aſcertained by undoubted experiments. It is certain that the geneſis and reciprocal tranſmutations of bodies are ſubjects ſo deep, that nothing concerning them ſhould be determined from a ſlight ſimilitude, or rude and imperfect experiments; theſe being matters which are only to be eſtabliſhed by the agreement of the moſt accurate analyſis and ſyntheſis. If we were at liberty to adapt obſervations, experiments, and the very nature of things, to preconceived theories, there would ſoon be an end to all the excellence and certainty of natural philoſophy, and that ſcience would be entirely overturned.

I ſhall, for the ſake of connection, briefly relate the diſcoveries of theſe two very expert chymiſts; but my chief labour ſhall be employed concerning thoſe circumſtances which they have either omitted, or touched upon but ſlightly.

## § II. *Preparation of Magneſia.*

This powder may be prepared in many different ways; the moſt pure is that precipitated from Epſom ſalt: ſcarcely more than half the weight of alkali of tartar is requiſite; but as that ſalt is expenſive,

ſive, pot-aſhes are generally uſed: however, as theſe are commonly mixed with vitriolated tartar, and with ſiliceous earth, nearly an equal quantity is neceſſary: both the ſalts ſhould be diſſolved in at leaſt a double quantity of pure water; after filtration, they are to be mixed and boiled, then ſet to ſtand at reſt, until a powder precipitates; the clear water is then poured off, and freſh warm water added; this again is to be poured off, and the operation repeated, until the precipitate is freed from all the heterogeneous matter, which can be waſhed away by water: finally, the whole reſiduum is to be dried upon a filter or a cloth.

100 parts of Epſom ſalt produce about 42 of aërated magneſia; but only 25 of magneſia which does not effervеſce with acids: this difference depends upon the precipitating alkali, as it is ſaturated with or deprived of aerial acid. In the former caſe, 58 parts of alkali are requiſite; in the latter, about 45;—the filtered liquor yields about 32 of vitriolated vegetable alkali.

The rationale of the operation is this:—the double portion of water, added to the two ſalts to be mixed, is not only ſufficient to diſſolve them, but alſo the vitriolated alkali which is generated by the mixture. The vitriolic acid of the Epſom ſalt attacks the alkali, and expels the aerial acid, if any be preſent, which unites intimately with the deſerted magneſia: but the boiling prevents the magneſia from being diſſolved in the water, by a ſuperabundance of the aerial acid. By calculation, 58 parts of alkali of tartar contain about 13 of aerial acid; 10½ of which are juſt ſufficient to ſaturate 19 of pure magneſia; 2½, therefore, are left to unite with the water: if this be equal or ſuperior to 1,388 parts, (for, in a moderate heat, water can take up at leaſt 0,0018 of its own weight), when thus ſaturated with aerial acid, therefore, it can take up nearly ⅕ of the precipitate, (§ IV.): the menſtruum, therefore, which diminiſhes the quantity of the maſs required, being volatile, muſt be expelled by heat. At firſt ſight, it cannot but appear very ſingular, that ſo much alkali is neceſſary to effect a complete precipitation; while, at the ſame time, not above 30 parts of vitriolated tartar are obtained, which contain at moſt but 17 parts of pure alkali: but we muſt in general take notice, that, to effect a complete decompoſition, the quantity of a precipitant which would be ſufficient to ſaturate the matter in a diſengaged ſtate, is by no means ſufficient; triple, quadruple, nay ſometimes ſextuple the quantity, being neceſſary: beſides, the alkali, which in this caſe is ſuperabundant, renders the vitriolated tartar more ſoluble; ſo that the whole does not eaſily cryſtallize.

The laſt lixivia of nitre, and of common ſalt, which refuſe to cryſtallize, contain magneſia, diſſolved in nitrous or marine acid; and the magneſia is collected by precipitation, evaporation to dryneſs, and calcination: if it is obtained from nitrous acid, it is called magneſia of nitre, to which the name of pulvis ſentinelli was formerly given;—that which is got from marine acid is called magneſia of common ſalt: the former always abounds in heterogeneous matter, particularly with lime; hence the nitrous lixivium yields more than four times the weight of powder which is obtained from the marine lixivium (*g*). The magneſia obtained by precipitation is very different from that obtained by calcination; as this latter can ſcarcely be entirely freed from marine acid; and beſides we ſhall ſee hereafter the effect of the fire (§ 111.).

### § 111. *Pure Magneſia.*

Common magneſia, after having been expoſed to a white heat, does not effervеſce with any acid:

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(*g*) 1 lb. of a nitrous ley affords, according to Spielman, 4 oz. of magneſia, by calcination, and 5 by precipitation. Margraaf, out of 1 lb. of marine ley, obtained 1 oz. 1½ drachm, and 10 grains, by alkali of tartar, and by volatile alkali 1 oz.: when volatile alkali is uſed, a ſalt, conſiſting of three ingredients, is found in the liquor, viz. of magneſia, volatile alkali, and vitriolic acid, which cannot be ſeparated by cryſtallization.—Hoffman, in the laſt ley of the ſalt-works at Hall, found magneſia.

the aerial acid being expelled by the fire. If the operation be properly conducted, 100 parts of magneſia will loſe 55 of their weight: this loſs is occaſioned by the expulſion both of the water and the aerial acid. If the heat be violent, and long continued, a greater loſs of weight is found to take place, as the violence of the fire is capable of diſſipating ſome even of the fixed parts.

After proper calcination, I call the magneſia pure, becauſe it is freed from water and aerial acid: but it can ſcarcely be obtained perfectly pure, except by means of the volatile alkali: for the fixed alkalis, when uſed as precipitants, adulterate the magneſia, frequently with lime, but always with ſiliceous earth; with which the alkali of tartar is found loaded, unleſs when cryſtallized: the mineral alkali, when properly reduced to cryſtals, is likewiſe free from ſiliceous earth. Calcined magneſia diſſolves in all the acids but ſlowly, and without efferveſcence; and in this ſtate requires about the ſame quantity of acid to ſaturate it as before the calcination; and forms, with the acids, the very ſame middle ſalts: it does not grow ſenſibly warm with water, nor does it diſſolve in it like lime; it is therefore a true earth, ſo far as can be collected from experiments hitherto made.

100 parts of pure magneſia, ſteeped in water, after drying are found to have increaſed in weight more than 18; whereas 100 of magneſia, ſaturated

ted with aerial acid, take up 66 (§ I.V.). The pure magneſia does not effervеſce in acids, but in great length of time, in the open air, it recovers this property by attracting aerial acid from the atmoſphere: why it diſſolves ſo very ſlowly in acids we ſhall ſee in § XIX.

Pure magneſia cannot deprive any alkali, except the volatile, of its aerial acid, as acids have a ſtronger affinity to them than to magneſia. It does not precipitate lime-water, but it precipitates all metals, not excepting platina, from their ſolution in acids with it: nitrated ſilver yields a black precipitate, and corroſive ſublimate one obſcurely red. It alſo decompoſes ammoniacal ſalts, but ſlowly; ſo that at firſt there is ſcarce any perceptible odour; but if the mixture be ſufficiently moiſtened, and kept 24 hours in a cloſe corked bottle, when the bottle is opened the volatile alkaline ſmell will be obſerved very unequivocally.

Magneſia expoſed for a long time to a very intenſe heat, begins to coaleſce, and ſhew ſigns of fuſion, particularly the magneſia which is obtained from the lixivia by calcination. It flows eaſily with borax, or with the microcoſmic ſalts: with equal parts of flint and borax it aſſumes the form of a beautiful glaſs like the topaz: with equal parts of flint and mineral fluor, a glaſs is produced of the colour of the chryſolite fuſed: with an equal weight of fluor mineral, it penetrates and diſſolves the crucible.

Magneſia, mixed almoſt in any proportion with lime, pure clay, and flint, flows in the fire; and, with a quadruple proportion of green glaſs, forms a maſs like porcelain, which gives fire with ſteel. —Even an equal weight of flint, of quick lime, of terra ponderoſa, of glaſs, of lead, of alkali of tartar, and finally of vitriolated tartar, will not flow alone with magneſia; but common clay runs with it into an hard maſs.

Glaſs cemented in magneſia reſembles porcelain (*h*).

## § IV. *Aerated Magneſia.*

That magneſia which is ſaturated with aerial acid I call aerated magneſia, becauſe it contains that acid which abounds in the atmoſpheric air: ſuch is that which is precipitated by a cryſtallized fixed alkali (§ II.); this effervеſces in acids, and by a ſlow ſaturation loſes 0,25 of its weight; the

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(*h*) M. Morveau here relates an experiment, in which he expoſed magneſia, and at the ſame time calcareous earth, to a violent heat: the former ſhewed no ſigns of fuſion, nor did it even adhere to the crucible; the calcareous earth was fuſed along with part of the bottom of the crucible. He had before aſſerted that magneſia was one of the moſt fuſible earths *per ſe*, and promoted very much the fuſion of other earths;—an opinion he now retracts. Macquer and d'Arcet had before ſhewn the refractorineſs of this earth. B.

ſubſtance,

ſubſtance, of which the expulſion occaſions this loſs, being collected by a proper apparatus, and examined, is found to poſſeſs all the qualities of aerial acid. Hence it follows, that 100 parts of aerated magneſia contain 25 of that acid, 30 of water, and 45 of an earthy matter diſtinct from all others hitherto known (§ III. and XIX.). Magneſia, fully aerated, contains 30 lb. in 100 of aerial acid: it is therefore in reality a medial earthy ſalt, of which (when completely cryſtallized) a kanne of diſtilled water, in a moderate heat, takes up 47 grains. Water ſaturated with aerial acid diſſolves a far greater quantity, even ſo far as an ounce and a quarter; provided the water, loaded with abundance of the acid, meets the magneſia minutely divided, as in the moment of precipitation, as it is in that ſtate more expoſed to the action of the ſurrounding menſtruum. A ſolution of this ſort in the open air is gradually deprived of its ſuperabundant acid, which flies off, and thence a portion of magneſia, which had been diſſolved, muſt ſeparate; this takes place firſt upon the ſurface, as it is there the volatile menſtruum firſt begins to be deficient. The pellicle which is formed, on examination is found to poſſeſs the properties not of lime, but of magneſia.

Evaporation being conducted leiſurely, cryſtals alſo appear, partly conſiſting of pellucid grains, partly of faſciculi of rays diverging from the ſame point (*i*). Diſtilled water, aerated, and ſaturated with magneſia, exhibits the following properties with precipitants.

(A) It makes paper weakly tinged with turnſole more diſtinctly blue; paper ſtained red by Brazil wood it makes blue; and induces a light brown upon the yellow of turmeric: ſo that at firſt we ſhould aſcribe theſe changes to an alkaline mixture, which adhered in the precipitation, and had eluded the waſhing; but this ſuſpicion ſoon falls to the ground, if we employ magneſia precipitated with volatile alkali, as this alkali produces the ſame changes of colour; but we muſt obſerve theſe changes quickly diſappear, together with the volatile ſubſtance which has occaſioned them; whereas thoſe made by magneſia, although precipitated by this alkali, are permanent; they therefore depend upon the earth alone.

(B) Upon the addition of acids, innumerable bubbles, extremely thin, float on the ſurface; theſe are occaſioned by the aerial expelled by the ſtronger acids.

(C) Aerated fixed alkali occaſions no change, unleſs the quantity of water be inſufficient for diſſolving the magneſia and the alkali both together; in which caſe the former is ſeparated: but if a pure cauſtic alkali be employed in proper quantity, the earth is immediately precipitated pure, i. e.

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(*i*) Tab. I. fig. 8.

incapable of efferveſcing with acids (§ 111.). Theſe alkalis are therefore capable of ſeparating aerial acid from magneſia.

Lime (which in its peculiar properties bears ſome analogy to fixed alkalis) in this caſe has the very ſame effects as fixed alkali; when ſaturated with aerial acid it occaſions no change, but lime-water or quick lime precipitates the magneſia pure.

The aerial acid adheres more readily to magneſia than to the volatile alkali; for if the former, when cauſtic, be added to the latter, and kept in a cloſe veſſel for ſome days, at length the alkali is found cauſtic, and the magneſia will efferveſce with acids. Another experiment ſeems indeed to overturn this; for magneſia diſſolved in water by means of aerial acid, is precipitated by pure volatile alkali: but it is to be obſerved, that here the precipitate efferveſces with acids, ſo that the alkali has taken away none but the ſuperabundant aerial acid; and the portion of magneſia, which was only held diſſolved by the ſuperabundance, neceſſarily falls to the bottom.

(D) All the middle ſalts, whether earthy or metallic, are precipitated by aerated magneſia, and that by means of a double elective attraction, as pure magneſia has not that effect. By this method lime and terra ponderoſa, diſſolved in other acids, are thrown down; for while their menſtrua ſeize the magneſia they themſelves fall to the bottom, united with the aerial acid, as appears from the increaſe of their weight, and their property of effervescing with acids.

The precipitates occaſioned by pure magneſia gain no increaſe of weight, and, if they be metallic, aſſume colours different from thoſe of the precipitates occaſioned by aerated magneſia: the latter ſeparates corroſive ſublimate of a darker colour, but after a few hours the colour of both precipitates is a reddiſh aſh-colour.

If to aerated magneſia, diſſolved in water, be added a ſolution of corroſive ſublimate, the mixture grows a little milky, and by degrees depoſits a quantity of white ſediment; then by little and little, firſt upon the ſurface, and afterwards at the bottom, thin blackiſh cryſtals concrete, compoſed of mercurius dulcis, and calx of mercury partly aerated.

The ſmalleſt drop of ſolution of mercury, in boiling nitrous acid, is inſtantly and copiouſly thrown down of a browniſh yellow colour, by water loaded with magneſia, by means of aerial acid: but the ſolution of the ſame metal, made in the cold, yields a white powder, which, after a few days, grows greyiſh; this happens becauſe the metal has loſt little of its phlogiſton.

## § v. *Vitriolated Magneſia.*

Vitriolated magneſia is called Engliſh ſalt, Epſom ſalt, Seydlitz or Seydſchutz ſalt, deriving a name from the place whence it comes; but theſe all differ very little from each other, except in the proportion of ſalited magneſia which they contain mixed with them. On account of its taſte it is vulgarly called bitter purging ſalt; but it is with more propriety called, from its nature, vitriolated magneſia, eſpecially when it is free from heterogeneous matters:—in cryſtallizing, it exhibits quadrangular priſms, with pyramidal apices, which are alſo quadrangular.

This ſalt is ſo eaſily ſoluble, that a kanne of diſtilled water, in a moderate heat, can take up 70½ ounces, but by boiling 140, before a pellicle appears; yet this laſt ſolution, when expoſed to cold, concretes totally.—The bulk of the water is encreaſed about 0,45, by the addition of the ſalt, and the heat of boiling; a circumſtance which ought to be taken particular notice of in determining the quantity of it; for in general the quantity of water is determined by the meaſure of the ſolution, which is always fallacious. If regular cryſtals are required, the evaporation muſt only be continued until a drop let fall on a cold ſurface concretes in a few minutes.

This ſalt, expoſed to a dry air, firſt loſes its tranſparency, and at length falls into a white powder: by complete calcination all the water of cryſtallization flies away; this water forms nearly one half of the whole, amounting to 0,48: hence therefore it appears, that 100 parts contain 19 of pure magneſia, 33 of vitriolic acid, and 48 of water (§ 111).

Fixed alkali quickly precipitates it, as well as the volatile alkali when aerated, nay even that which is commonly conſidered as pure. This laſt caſe ſeems to indicate a doubt with reſpect to the degree of affinity;—as pure magneſia, added to a ſolution of that ſalt which is called ſecret ammoniac, and kept for ſome days in a bottle cloſely ſtopped, diſcovers, upon opening the bottle, a diſtinct odour of volatile alkali: this precipitation may be attributed to other cauſes. Thus the volatile alkali can ſcarcely be procured perfectly pure, being either adulterated with water or aerial acid: beſides, the pureſt, when expoſed ever ſo little to the open air, or to air newly expelled from the lungs, inſtantly attracts a portion of that acid; and thus, by a double elective attraction, acquires the property of being decompoſed: yet the precipitate occaſioned by the volatile alkali generally exhibits, on ſolution, very ſlight marks of efferveſcence: this the love of truth obliges me to confeſs; ſo that if this precipitation be owing to the aerial acid, it is evident that a much ſmaller quantity of it ſuffices for this purpoſe than for ſaturation: but theſe cauſes are accidental; there is one, however, which is conſtant, *v. g.* the volatile alkali is very ſtrongly united with magneſia and vitriolic acid; now in this triple ſalt the acid, formerly entirely attached to the magneſia, muſt be divided in a certain ratio between the two; and hence the magneſia, which does not enter into this new union, is ſeparated, and falls to the bottom.

Lime-water ſeparates magneſia from the vitriolic acid, although crude or aerated lime has no effect; hence it evidently appears how much the efficacy of this ſubſtance is affected merely by an union with aerial acid.

The acid of ſugar, added in proper quantity, takes away the whole earthy baſis from the vitriolic acid, and precipitates it to the bottom in the form of a white powder, eſpecially if the ſolution be inſpiſſated by gentle evaporation; for otherwiſe, by means of the ſuperabundant acid, the greater part is held ſuſpended.

In the ſame manner the vitriolic (which in power of attraction is among the ſtrongeſt) yields magneſia to the fluor acid: at firſt a very ſmall ſediment falls, but during evaporation the fluorated magneſia by degrees appears; in this caſe, however, heat muſt be carefully avoided, as by it the more volatile of the menſtrua are much weakened. The vitriolic acid is alſo expelled by the acid of phoſphorus, at leaſt when the watery part is ſufficiently diminiſhed by evaporation; ſpirit of wine coagulates the mixture in the ſame manner as it does with phoſphorated magneſia.

Rectified ſpirit of wine does not take up vitriolated magneſia, which may by it, therefore, be ſeparated from water. In proportion as the ſolution is more ſaturated, and the ſpirit more pure, the coagulation happens more quickly; ſo that in a few minutes the whole mixture will concrete into a ſolid maſs.

The Seydlitz, Seydſchutz, or Epſom ſalts (*k*) are got by evaporation from the water of fountains, in the places from whence they borrow their names. Theſe waters contain other ſubſtances, and from hence, excluſive of the difference in exſiccation, the ſalts vary; hence the Seydlitz ſalt ſcarcely attracts moiſture from the air. The Epſom or Engliſh ſalt is prepared from ſea-water, after the cryſtallizations of the common ſalt, by boiling, and by adding colcothar of vitriol, which contains a portion of acid; this acid, quitting the iron, unites with the magneſia, and produces a cryſtallizable bitter ſalt. That which comes to us under the form of cryſtalline aciculæ contains ſo much ſalited magneſia, either united with the water of cryſtallization or adhering externally, that it eaſily deliqueſces by the moiſture of the air.

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(*k*) The Epſom ſalt was firſt noticed by Grew in 1675; but as only a much ſmaller quantity than was uſed could be got from ſprings, chymiſts anxiouſly ſought for an artificial mode of compoſing it. Hankwitz prepared it at London, from common ſalt, or the laſt ley of this and calcined vitriol, Eph. N. C. cent. 3. and 4. Others found it in different ſprings: Bertrams, in thoſe at Creutzburg; Gehrardten in thoſe at Oberneuſultz, &c.

air. The cryſtals of this ſalt are ſometimes ſo large that they are ſold for Glauber's ſalt; and on the other hand, in France, Glauber's ſalt, being reduced to ſmall ſpiculæ, by agitating it during the cryſtallization, is ſold for Epſom ſalt.

Theſe frauds are indeed of little conſequence, yet they throw a veil over the truth, and are not eaſily diſcovered. Thus, lime-water does not precipitate genuine Glauber's ſalt; but Epſom ſalt inſtantly yields up its acid to the lime, and a ſelenites, together with the deſerted magneſia, falls to the bottom.

Vitriolated magneſia does not give up its acid on diſtillation.

Phlogiſticated vitriolic acid alſo diſſolves magneſia; but the middle ſalt, ariſing from this combination, is eaſily diſtinguiſhed from Epſom ſalt by its taſte; it alſo yields ſmaller cryſtals, and, upon the addition of any acid, even vinegar, it gives out a pungent and ſuffocating vapour: it is ſeparated from water by ſpirit of wine, although, by the acceſſion of phlogiſton, it ſhould ſeem to approach nearer to that inflammable menſtruum.

## § VI. *Nitrated Magneſia.*

The nitrous acid, ſaturated with magneſia, after proper evaporation, yields priſmatic, quadrangular, ſpathous cryſtals, witho[illegible] poſſeſs an acrid, and, at the [illegible] ceeding bitter taſte, and eaſily deliqueſce in the air: if paper be moiſtened with a dilute ſolution of it, after drying, it burns with a green flame; which colour aqua fortis alone, in the ſame way, frequently exhibits.

The acids of fluor, of ſugar, of phoſphorus, and vitriol, take away magneſia from the nitrous, a circumſtance which yet eſcapes obſervation, for theſe new combinations are ſoluble in nitrous acid; they may, however, be brought into view either by evaporation, or by dropping in highly rectified ſpirit of wine, as this, by abſorbing the water, precipitates the ſalts.

Nitrated magneſia yields its acid on diſtillation; it diſſolves completely in ſpirit of wine: in this caſe, however, its flame is not green, but becomes larger and more vivid than before.

Phlogiſticated nitrous acid ſaturated with magneſia, betrays itſelf by its taſte, and, on the addition of any, even the vegetable acid, by its ſmell; but theſe principles are ſcarcely ſeparated by the phlogiſticated vitriolic acid; at leaſt the addition of rectified ſpirit of wine occaſions no coagulation (*l*).

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(*l*) "Lime-water decompoſes nitrated magneſia. In a memoir on the treatment of the mother leys of nitre, I have pointed out this proceſs as very advantageous, not [illegible] completing the analyſis of them, but alſo for ſe[illegible] magneſia from calcareous earth, at ſmall expence."

Morveau.

§ VII.

## § VII. *Salited Magneſia.*

Magneſia, diſſolved in marine acid, has an exceeding bitter taſte, and cannot be cryſtallized; unleſs, after being much inſpiſſated by heat, it be expoſed ſuddenly to extreme cold; but the aciculæ which concrete upon this occaſion ſoon deliqueſce by the moiſture of the atmoſphere. While the marine acid diſſolves magneſia, its tranſparency is ſomewhat obſcured; and when the ſaturation is finiſhed, the ſolution quickly concretes into a jelly of a watery colour; which, if diluted while warm, yields ſpongy maſſes, not ſoluble even in marine acid: a jelly of this ſort is produced by the acids of nitre, of ants, of vinegar, and others, but does not appear in the filtered ſolutions; for the moiſture being in a great meaſure diſſipated, theſe yield a viſcid matter like gum, which, when well waſhed, is found to be ſiliceous (§ XV.) owing to the impurity of the precipitating alkali.

If aerated magneſia be employed, the aerial acid which is ſeparated is partly abſorbed by the water, which, by this means, takes up a portion of the magneſia without any other aſſiſtance: hence, when the ſolution is finiſhed, it changes vegetable colours like an alkali (§ IV. A.); which is true not only of the ſolution made by marine acid, but of all others, unleſs the acid ſolvent ſuperabundant. If, therefore, an exact ſaturation be required, it is more eaſily had by pure magneſia; for if aerated, in order to anſwer the end, an accuracy extremely troubleſome is requiſite; for either the ſuperfluous aerial acid muſt be expelled, or the ſaturation muſt be determined by repeated trials.

Salited magneſia diſſolves in ſpirit of wine, and is ſubject to the ſame laws of affinity as the nitrated, except that this is ſoluble in nitrous acid; for on adding that acid, and evaporating, nitrated magneſia is formed; beſides, the acid of ants unites intimately with ſalited magneſia, forming a cryſtallizable ſalt compounded of three ingredients: this combination yields its acid to a diſtilling heat.

## § VIII. *Fluorated Magneſia.*

The fluor acid (*m*) at firſt violently attacks magneſia; but as the ſaturation approaches, certain particles, almoſt inſoluble, are ſeparated; and at length, when the ſaturation is complete, the water, which hardly diſſolves the fluorated magneſia, lets fall at once all that the ſuperabundant acid had taken up.

(*m*) This acid was deſcribed by its experienced inventor Mr Scheele, in the Stockholm Tranſ. for 1771.

That portion which can be diſſolved by means of abundance of acid, on ſpontaneous evaporation concretes above the liquor to the ſides of the veſſel, in the form of a tranſparent mucilage, marked with long and very ſlender cryſtalline threads; but at the bottom we find ſpathoſe cryſtals, which, though not eaſily diſſolved, are yet not entirely rejected by ſpirit of wine. Their form is hexangular priſms, ending in a low pyramid compoſed of three rhombi.

Neither vitriolic, nor any other acid, decompoſes fluorated magneſia by the humid way: this combination, when alone, and pure, does not yield its acid in the moſt intenſe heat of diſtillation.

## § IX. *Arſenicated Magneſia.*

The acid of arſenic (*n*), united to ſaturation with magneſia, is with much difficulty ſoluble in water; and therefore, like the former combination, the whole ſubſides, and is again diſſolved, if ſuperabundance of acid be added: upon evaporation it then yields no cryſtals, but a viſcid maſs like gum, which is not precipitated by ſpirit of wine; yet it is worth obſerving, that the acid of arſenic, added to acetated magneſia, which like-

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(*n*) This acid will be ſoon deſcribed by Mr Scheele, in the Stockholm Tranſ. See Diſſ. XXI. vol. ii.

wiſe forms nothing but a viſcid maſs (§ XIII.) produces elegant priſmatic cryſtals, which may be called ſolar, as many of them diverge like rays from a point; the reaſon is doubtleſs this:—the acid of arſenic, unleſs when ſuperabundant, cannot ſuſpend the magneſia, but all ſuperfluous acid impedes cryſtallization; now the acetous acid diſſolves the arſenicated magneſia, and ſuffers it to concrete into cryſtals by a ſlow evaporation; and the ſame thing takes place, if the acetous acid be expelled from the magneſia by the acid of arſenic: theſe cryſtals, in a long continued heat, calcine ſo far as to grow opake and white. What has been now ſaid of vinegar holds with reſpect to nitrous acid, marine, and the acid of ants; by all which arſenicated magneſia is not decompoſed, but diſſolved, and yields ſolar cryſtals: this ſeems to afford a method of cryſtallizing ſalts which are difficultly ſoluble (§ X. XV.); viz. let the water be ſharpened with ſome ſuitable acid, which will not alter the ſalt required (*o*).

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(*o*) This proceſs opens a new field for obſervations; it will be uſeful on many occaſions: but I doubt whether a pure ſalt can be by theſe means obtained; the ſuppoſition appears repugnant to the general and conſtant laws of ſolution; for a cryſtallizing body always, of neceſſity, retains a portion of the diſſolving fluid; this, in the ſalts, is called the water of cryſtallization: and if vinegar here performs the office of water muſt not the ſalt retain the vinegar of cryſtallization? This caſe is different from the precipitation

The fluor acid, the acid of ſugar, of phoſphorus, and vitriol, ſeparate magneſia from the acid of arſenic; but the acid of tartar, united with arſenicated magneſia, is generally found to compoſe a triple ſalt.

This ſalt is not decompoſed by fire, unleſs with the addition of phlogiſton; in which caſe the acid intimately united with it generates a regulus.

### § x. *Boraxated Magneſia.*

The ſaline ſubſtance which in borax is united to the mineral alkali, and is called the ſedative ſalt by Homberg, ſhews, upon examination, undoubted

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precipitation of ſalts by ſpirit of wine, which is only a ſudden abſorption of the water, and requires that the ſalt ſhould not be ſoluble in the added liquid: on the contrary, we are forced to admit a real affinity of the fluid with the ſalt, a gradual approximation not of the ſalt only, but of the integrant parts of the ſolution itſelf, in conſequence of the evaporation of the ſuperabundant portion of the ſolvent; it is therefore impoſſible that this adheſion of the principles ſhould ceaſe ſuddenly, without any new cauſe ſupervening; or that the ſalt, thus abandoned, ſhould aſſume a regular form. To object the uniformity of cryſtals produced in this manner in different acids, is in vain: that the two principles conſtantly exiſting in theſe combinations ſhould, with reſpect to cryſtallization, be endowed with properties that a third cannot deſtroy, is, I think, much more probable; it is certainly not without example, even in the ſimple ſalts. Morveau.

doubted though weak marks of an acid nature, it even attacks ſome metals, &c.

If magneſia be put into a ſolution of this, it will be diſſolved, though very ſlowly, on account of the weakneſs of the menſtruum. On evaporation irregular cryſtalline grains appear: the principle of connection in theſe being very weak, they may be ſeparated in the humid way by other acids; even ſpirit of wine ſeparates them, but takes up a part of the acid: vinegar and acid of ants diſſolve this ſalt entirely; and, when the moiſture is diſſipated, it appears in the form of ſpiculæ, on which others ſtand at right angles: it flows in the fire, and that without any decompoſition; nay, the acid of borax expels from magneſia, by the aſſiſtance of heat, all the acids which are volatilized by heat.

## § XI. *Saccharated Magneſia.*

The peculiar acid which reſides in ſugar has already been deſcribed, together with the beſt method of obtaining it pure: this diſſolves magneſia, and holds a great quantity of it ſuſpended; but when ſaturated, it falls to the bottom, refuſing to unite with water, which has already been obſerved in other inſtances (§ VIII. IX.): it is ſcarcely ſoluble in ſpirit of wine.

The fluor acid alone is capable of taking magneſia from acid of ſugar by the humid way.

This ſalt, when ignited, ſends forth all its acid;

nor

nor does it ſhew any veſtiges of a coal, as the tartariſated magneſia does, as we ſhall ſee in the following ſection.

## § XII. *Tartariſated Magneſia.*

The genuine (*p*) acid of tartar takes up magneſia in the very ſame way as the former acid; and the portion which is ſuſpended by a ſuperabundant acid falls by evaporation in polygonal tranſparent grains, reſembling ſhort hexangular priſms truncated at both ends, and more or leſs irregular: ſpirit of wine with difficulty attacks this ſalt; and therefore, when added to a ſolution of it in water, immediately throws down cryſtalline grains.

The acids of fluor, ſugar, phoſphorus, vitriol, nitre, and ſalt, decompoſe tartariſated magneſia.

This ſalt readily melts in the fire, boils, ſwells, and yields a coal, which, when burned, at length leaves the magneſia free.

## § XIII. *Acetated Magneſia.*

Vinegar, though loaded to ſaturation with magneſia, yet diſſolves readily in water: however evaporation be conducted, no cryſtals are obtained; but at length a viſcid deliqueſcent maſs appears,

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(*p*) See the Stockholm Tranſ. for 1770.

which parts with the vinegar on diſtillation. Spirit of wine may be completely mixed with this ſaline liquor.

All the acids, except phlogiſticated vitriolic and nitrous acids, and the aerial acid, decompoſe acetated magneſia.

## § XIV. *Formicated Magneſia.*

The acid of ants, when ſaturated with magneſia, quits the water, and falls to the bottom: this is again ſoluble in ſuperabundant acid, and depoſits cryſtals upon evaporation, which are very difficultly ſoluble in water, are void of taſte, do not melt in the fire, but ſwell and decrepitate a little, ſoon grow black, and ſplit at length into a white powder, which effervesces with acids; becauſe the acid of ants, when it is deſtroyed, yields aerial acid to the magneſia: the figure of the cryſtals is hemiſpheric, the cutting plane being oblique, a little concave, poliſhed, with ſtriæ (which are ſcarce diſtinguiſhable by a glaſs) diverging from a center very like the tubercles of liverwort: hence the acid of ants is readily diſtinguiſhed from vinegar, to which, in other reſpects, it is very like; it, as well as phlogiſticated vitriolic and nitrous acid, takes away magneſia from the acid of ants: one half the weight of this ſalt is magneſia; one part of it requires thirteen of water to diſſolve it in a moderate heat: ſpirit of wine does not take it up (*q*).

## § XV. *Phoſphorated Magneſia.*

The acid of phoſphorus takes up magneſia almoſt in the ſame way as the former; but that which is taken up by a ſuperabundant acid, as ſoon as evaporation begins, yields cryſtalline grains, which are ſomewhat larger in acetated magneſia when the acid of phoſphorus has been previouſly added; and that for the reaſon aſſigned (§ IX.); at length, however, the whole liquor falls into a viſcid maſs.

By the humid way the acid of phoſphorus takes away magneſia from all the acids, except the fluor acid and acid of ſugar—by the dry way all the volatile acids are expelled.

A ſolution of phoſphorated magneſia grows cloudy upon the addition of ſpirit of wine; but when the ſpirit is diſſipated by evaporation, the clouds again diſappear.

In general, it is proper to obſerve, that ſolutions of common magneſia, in all the acids, are of an opal colour, occaſioned by ſiliceous atoms which remain upon the filter; but, when

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(*q*) If the ſmalleſt quantity of calcareous earth be mixed with magneſia, ſparry cryſtals are formed, which effloreſce in the air. See J. Afzelius on the Acid of Ants.

that operation is neglected, fall by degrees to the bottom, and concrete into a gelatinous maſs (§ III.).

### § XVI. *Whether Magneſia be ſoluble in alkaline Salts.*

Some bodies are of ſuch a nature, that they poſſeſs an attraction both for acids and alkaline menſtrua. Among theſe it will be ſufficient to mention copper, which is diſſolved, not only by acids, but by alkali, eſpecially the volatile, which forms with this metal a cryſtallizable ſalt; it has been properly enough doubted, whether magneſia was one of this kind of bodies. Margraaf, in the precipitation of magneſia, cautions us againſt the uſe of too much alkali, particularly the mineral and volatile, as theſe again diminiſh the quantity of precipitate which had been before thrown down: with that noble candour with which this illuſtrious man always relates his experiments, he confeſſes, at the ſame time, that he could not effect a direct ſolution, although ſome bubbles appeared, which ſeemed to indicate ſome kind of action in the menſtruum. In this very buſineſs all my labour, too, was in vain; but we now know that the earth, after having been thrown down, may again diſappear by another medium, viz. aerial acid (§ II.) To this, therefore, and not to the ſole action of the alkali, are we to attribute this phænomenon; eſpecially as the circumſtances attending it agree exactly with the nature of the alkalis; for, in the ſame weight, volatile alkali contains more aerial acid than the fixed mineral; and the vegetable leaſt of all (r).

## § XVII. *Magneſia diſſolves Sulphur.*

Magneſia attacks ſulphur both by the dry and the humid way; but the connection of theſe ſubſtances is ſo looſe, that they ſoon ſeparate in the open air. Let $\frac{2}{3}$ of a bottle, containing a pound, be filled with diſtilled water; let a handful of magneſia, and as much flower of ſulphur, be put in; let the air included above the liquor be rarefied by heat, and the bottle then ſhut cloſe; let it be then kept in balneo mariæ for ſome hours; and, after cooling ſufficiently, when the orifice is opened, a manifeſt hepatic odour ſtrikes the noſtrils; but the water itſelf, when filtered, yields, with a lixivium of fixed alkali, a ſediment, which is ſoluble in acids. With ſolution of ſilver, it grows black and turbid; as alſo with ſaccharum ſaturni: on ſpontaneous evaporation, the bottom of the veſſel is, at length, found covered with a pellicle, interſperſed with cryſtalline aciculæ, which diſſolve with effervеſcence in acids, except a greyiſh powder, which, thrown on live coals, gives out a ſulphureous ſmell, but no flame; which undoubtedly ariſes from hence, that the ſulphur is impure, being enveloped with ſaline particles.

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(r) See Diſſertation I. § VIII.

## § XVIII. *Elective Attractions of Magneſia.*

The phænomena above related, point out the following order of elective attractions, in the humid way, viz. firſt fluor acid (§ X.—XV.); acid of ſugar (VIII. XI. XV.); phoſphoric acid (XI. XV. V.); vitriolic acid (XV. V. IX.); arſenical acid (IX. V. VI.); nitrous acid (IX. VI. VII.); marine acid (VI. VII. XII.); acid of tartar (VII. XII. X.); acid of ants (X. XIV. XIII.); acetous acid (XIV. XIII. VI.); acid of borax (XII. X. XIV.); phlogiſticated vitriolic acid (VI. V.); phlogiſticated nitrous acid (XIII. VI. V.); aerial acid (IV.); water (III.); and ſulphur (XVII.).

In the dry way, the order is different; for in this the more fixed, though weaker acid, by means of the heat, overpowers the volatile, tho' ſtronger. Let $M$ denote any ſubſtance attracted by two menſtrua; the ſtronger, in a moderate heat, by the elective attraction $A$, the weaker by the elective attraction $a$; let us then ſuppoſe the firſt more volatile in the fire, and denote its niſus to riſe by $V$, and the niſus of the other by $v$: it now appears, that $M$ is attracted by a force $= A - a$; but let the heat be continually increaſed, and this force will be continually changed. Now, ſince $V$ increaſes more than $v$, at length $A - a$ will be $= V - v$; but when the fire is further increaſed, the equilibrium will be deſtroyed, and the menſtruum, which was before weaker, will prevail. The caſe will be more ſimple, if we ſuppoſe the weaker menſtruum entirely fixed, that is $v = o$. In the Treatiſe on Elective Attraction, we ſhall examine more minutely how fire encreaſes the volatility of bodies.

Hence the acids which are fixed, ſuch as thoſe of phoſphorus, arſenic, and borax, are found to prevail over all others; and from experiments the foregoing table is to be altered in the following manner, viz. acid of phoſphorus, of arſenic, of borax, vitriolic acid, acid of ſugar, nitrous acid, marine acid, acid of fluor, of ants, of vinegar, phlogiſticated vitriolic and nitrous acids, and, laſt, aerial acid. The acid of tartar has no place here, as it is deſtroyed by a ſufficient degree of fire.

## § XIX. *Magneſia differs from Lime.*

Magneſia and lime agree in this reſpect, that they both diſſolve in acids, with efferveſcence; yet terra ponderoſa and aerated alkaline ſalts poſſeſs the very ſame property; a circumſtance which indicates no more than the preſence of aerial acid in all of them. But if they are examined more cloſely, we ſhall find a remarkable diſſimilitude;

the particulars of which we ſhall briefly relate, that the true nature of magneſia may be better and more diſtinctly known.

Water takes up aerated magneſia (not aerated lime). Magneſia, after a ſufficient calcination, is rendered inſoluble, (lime ſoluble). Pure magneſia makes none but the volatile alkali cauſtic, (lime imparts cauſticity alſo to fixed alkali). Magneſia, when ſaturated with vitriolic acid, conſtitutes a bitter ſalt, ſoluble in about an equal weight of water, (lime yields a ſelenite almoſt inſipid, one part of which requires more than 400 of water). Magneſia, with nitrous acid, produces a cryſtallizable ſalt, (nitrated lime can ſcarcely be brought to cryſtallize). Magneſia, with marine acid, forms a liquor, which, on diſtillation, eaſily loſes the menſtruum, (lime does not). Magneſia, with vinegar, refuſes to cryſtallize, (lime exhibits ſeveral ſingular vegetations). Magneſia is not thrown down from other acids by vitriolic acid, (lime produces gypſum, which inſtantly falls to the bottom). Magneſia attracts the fluor acid, in preference to all others, then the acid of ſugar, and the reſt as above deſcribed, (lime effects the ſame menſtrua in a very different order). There are many other circumſtances already mentioned, which, compared with the known properties of lime, will evidently ſhew the difference.

So great and ſo conſtant is the difference, that theſe ſubſtances ought no more to be confounded.

As the magneſia obtained from the nitrous lixivium is almoſt always mixed with lime, in accurate examination this impure earth ſhould not be employed: whoever wiſhes, then, to examine the true nature of magneſia, ſhould employ the baſe of the ſal amarus, as that, if rightly prepared, will never deceive him.

But it has been ſuggeſted, that magneſia is lime altered, putting on, *pro re nata*, now the ſhape of lime, now entirely putting it off; it is ſcarcely poſſible, that the ſame ſubſtance ſhould acquire properties ſo different: in the mean time, while we are only ſpeaking of poſſibility, we can ſay no more than that, as yet, chymiſtry labours under ſo great imperfection, that it cannot, *a priori*, determine whether or not the powers of nature be ſufficient to effect ſuch a metamorphoſis; but we muſt not, from a bare or diſtant poſſibility, believe the real exiſtence of transformation.

The expert are not diſturbed by vague aſſertions. Accurate experiments, both analytic and ſynthetic, and theſe accurately employed, at all times and in all places afford the ſame reſults: the vitriolic acid, ſaturated with lime, produces gypſum; with magneſia the ſal amarus, and that conſtantly. In order to obtain gypſum from lime-water, we need no other artifice than a perfect ſaturation: if the acid menſtruum is ſuperabundant, gypſum is indeed produced, but ſo much penetrated by the acid, as to deliquiate in the air, to preſerve its poliſh long in the fire, and to flow very readily; but if this acid be ſuperfluous, or ſaturated or ſeparated by means of ſpirit of wine, a true gypſum appears; which will hereafter be ſeen, when we examine lime. Varieties, occaſioned by the abundance or deficiency of a proximate principle, cannot properly be called tranſmutations;—the vitriolic acid remains truly and totally, in itſelf, unchanged; the ſame may be ſaid of lime; although, according to the variety of quantity in each, they may both be varied three different ways: for either they are both ſaturated, or the acid abounds, or it is deficient; in each of theſe caſes a true gypſum is produced; but in the ſecond caſe it is loaded with a diſengaged acid; in the third, with a lime not diſſolved; and hence its nature and properties muſt be more or leſs obſcured: that this is the caſe is evident; and beſides, theſe two principles may be again ſeparated in all reſpects the ſame as they had been before their union; a circumſtance which does not agree with a real tranſmutation; at leaſt, if the meaning of that word be extended ſo far, it will apply to all the neutral and middle ſalts.

At the time when men were ignorant of the true preparation of Epſom ſalt, various opinions were entertained upon that ſubject; and among others, it was thought, that lime, firſt diſſolved in marine acid, then precipitated by vitriolic acid, filtered, and evaporated to a pellicle, would yield true Epſom ſalt. But whoever tries the experiment will ſoon find, that the precipitate firſt thrown down, and the aciculæ after, when waſhed in ſpirit of wine, are no other than perfect gypſum: this, on account of its being but juſt made, and therefore not yet deprived of the adhering liquor, has a taſte acid, and ſomewhat bitter, partly occaſioned by the marine acid ſtill diſengaged, and partly from the lime: but if, by means of filtration through paper, or, which is better, by ſpirit of wine, it be deprived of its liquor, it ſhews all the properties of genuine gypſum, unleſs magneſia be mixed with the lime, as we ſhall afterwards ſee (§ xx.). In this caſe, therefore, there is no real tranſmutation; which, if it took place, would undoubtedly prevent the production of the ſmalleſt particle of vitriolated magneſia.

Nor ſhall we ſucceed better, if, according to the directions of others, lime precipitated from nitrous or marine acid be moiſtened, and afterwards expoſed to calcination, with ever ſo great caution: certainly, by this method, nothing more can be had than lime more or leſs impregnated with the acid, in proportion as the degree of heat has been leſs or greater.

Magneſia, precipitated by an alkaline ſalt from lixivium of nitre, is readily diſſolved in vitriolic acid, yielding that ſalt which goes by the name of Epſom ſalt; but that which is got by evaporation and calcination neither effervеſces, nor ſeems to be diminiſhed in that menſtruum.—Hence magneſia is ſuppoſed to be transformed into lime by means of fire; but the true reaſon of the phænomenon is very different:—the acid attacks calcined magneſia, indeed, but very ſlowly; for the part of the menſtruum which lies next round it, becoming ſpecifically heavier, ſinks to the bottom, preventing the acceſs of the diſengaged acid; by degrees, however, the acid penetrates; ſo that if a ſufficient quantity be added, it will at length take up the whole of the magneſia, which is not the caſe with lime: an inteſtine motion of the liquor accelerates all ſolutions; and hence it is that aerated magneſia quickly vaniſhes; for the aerial acid, being expelled by the ſtronger acid, breaks forth in innumerable bubbles, which agitate and diſplace the ſeveral particles, ſo that the acid is perpetually in contact with the magneſia: for the ſame reaſon calcined lime and terra ponderoſa are diſſolved more ſlowly than when they are aerated.

Others contend that magneſia is generated from clay, by means of vitriolic acid; and this I will readily grant to be the caſe, provided any one can ſhew a method by which pure clay can be thus changed;—conjectures and opinions ſhould depend upon or be formed by experiments. With vitriolic acid they obtain from common clay the earth of alum, which being afterwards mechanically and carefully mixed with ſiliceous earth, again regenerates common clay (*s*). From what has been ſaid it appears, that magneſia is an earth diſtinct from all others, whether ſimple or compound we will not take upon us to decide; the ſame is alſo true of lime: but as in all the experiments hitherto inſtituted they preſerve conſtant properties, and are never decompoſed, they ought to be reckoned among the ſimple bodies, until a faithful analyſis, confirmed by a proper ſyntheſis, reveal their origin. That man will certainly deſerve well of the ſcience of chymiſtry who ſhall ſhew, not by forged opinions, but by undoubted experiments (which, at all times and in all places, will ſtand the moſt rigorous teſt) that magneſia owes its origin to lime or clay.

## § XX. *In what State Magneſia occurs upon the Surface of the Earth.*

Magneſia is leſs common than other primitive earths; or, to ſpeak more properly, it is ſo mixed with

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(*s*) See Margraaf, vol. ii. p. 49. he concludes "this earth is neither calcareous nor aluminous;"—p. 10. and 11. he ſays, "the objections of a certain chymiſt on this ſubject are ſo trifling, that to anſwer them would be loſs of time: I ſhall only ſay, that clay may be recompoſed juſt the ſame as before, by putting together its conſtituent parts; wherefore no tranſmutation is produced by the vitriolic acid, nor any new ſubſtance produced during the operation."

with other matters, that it can neither be immediately diſtinguiſhed, nor often freed from heterogeneous matters, without the help of acid menſtrua. Magneſia, as well as clay, is an exceeding fine light and ſpongy earth, and therefore the very pureſt of them, buried in the earth, muſt neceſſarily be ſoon mixed with heterogeneous particles. Magneſia, lime, terra ponderoſa, clay, and flint, if reduced to a fine powder, and ground together, along with water, cannot afterwards be ſeparated from each other but by fit menſtrua. It would however be highly abſurd to deny that theſe ſubſtances are contained in their perfect ſtate in the mixture; and to aſſert, that they are produced by the action of acids.

All theſe (except the laſt, which refuſes to unite with ordinary acids) though diſſolved and precipitated 30 times, were yet found abſolutely unchanged: the only variety which occurred was with reſpect to the three firſt, which appeared cauſtic or mild, according as the precipitating alkali had been either aerated or pure: beſides, not one of theſe five earths could, by means of any menſtruum hitherto tried, be actually tranſmuted into another; ſo that, conſiſtently with the rules of right reaſoning, we cannot deny the exiſtence of magneſia, although it is often ſo enveloped in heterogeneous matter that it cannot be extricated without the help of acid menſtrua. In many bitter waters we find magneſia combined with vitriolic [illegible] has lately diſco[illegible] [illegible] and elixated, [illegible] as occurs in our alu[illegible] [illegible] quantity.

[illegible] Salberg, upon the ſurface [illegible] heaped up [illegible] the ore by waſhing, [illegible] examined, is often [illegible], of ſal amarus; [illegible] earth, which, [illegible] magneſia ſome[illegible]. [illegible] alſo preſent grains of [illegible] calcination, form [illegible] gypſum, and with the [illegible]

[illegible] acid in all ni[illegible] acid in great quan[illegible] water of the ocean; [illegible] the diſagreeable bit[illegible]

[illegible] ſtate in which we [illegible] mineral waters, as [illegible] deſtitute of every a[illegible]—Let me aſk, what acid it is [illegible]: as we ſee it can be ſepa[illegible]?

[illegible] clays, with lime, and ſilice[illegible] a ſingular variety of marl.

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[illegible] IX. of the Preparation of Alum.

It is found in the terra lemnia, combined with clay, flint, and martial earth; it alſo enters into the compoſition of various ſtones; with flint it is united in the ſteatite and ſerpentinum; with flint and lime in aſbeſtos; with flint and clay in mica.—It is alſo hidden in calcareous ſtones which have been long buried in the ſea, conſiſting of impalpable particles; and in many others not yet ſufficiently examined.

Garnets alone never form entire mountains; yet we cannot from thence doubt of their exiſtence.—The ſame may be ſaid of pure quartz, and others.

Therefore, although no one has yet ſeen thick ſtrata, or huge heaps of magneſia, yet it is formed in a perfect ſtate upon the ſurface of the earth; and the chymical analyſis of earths and ſtones diſcovers it, partly mixed mechanically with other matters, partly diſſolved;—neither its quantity nor bulk can change the nature of the thing itſelf: we are forced to give up ſuch tranſmutations, as not only being fallacious, and not founded upon ſufficient experiments, but as contradicting each other:—for ſome pretend that magneſia is produced from lime, others from clay, a third from the earth of alum, and, what is obſervable, that this may be done by the vitriolic acid. But we are not enquiring what may poſſibly be done, being intent on diſcovering what plain experiments ſhew to have been actually done.

## § XXI. *The Uſes of Magneſia.*

Magneſia has hitherto been only uſed in the apothecary's ſhop; and it acts in a different way, according as it is crude, or calcined, or combined with an acid:—when crude it deſtroys acidities in the *primæ viæ*, but at the ſame time giving out its aerial acid, occaſions in ſome perſons conſiderable inconveniencies (*v*). It accelerates the putrefaction of fleſh more than chalk, crabs claws, or the other teſtaceous powders; but retards that of the bile (*u*).

Half the doſe of calcined magneſia equally opens the bowels, and deſtroys acidity, and that without any inconvenience. It not only preſerves fleſh long, but in a ſingular manner reſtores bile already corrupted: taken in equal proportions, with camphor, opium, guaiacum, ſtorax, maſtic, aſſafœtida, myrrh, ſcammony, and other gum-reſins or pure reſins, and triturated with water, it yields very uſeful tinctures; for upon filtration they appear clear and ſaturated, without any thing cauſtic, as calcined magneſia refuſes to diſſolve:

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(*v*) Quandoque flatulentias et morſicationes in imo ventre relinquit, ſi frequentiùs in uſum trahitur, primaque regio, progignendis corroſivis ſuccis, ut in hypochondriacis fieri ſolet, expoſita eſt.

(*u*) Henry on Magneſia.

but theſe tinctures muſt be only made when wanted.

Every one knows the cathartic uſe of vitriolated magneſia.

The uſe of magneſia in rural œconomy muſt be left to the examination of manures.

END OF THE FIRST VOLUME.

BIBLIOTHECA BODLEIANA

Fig. 4.

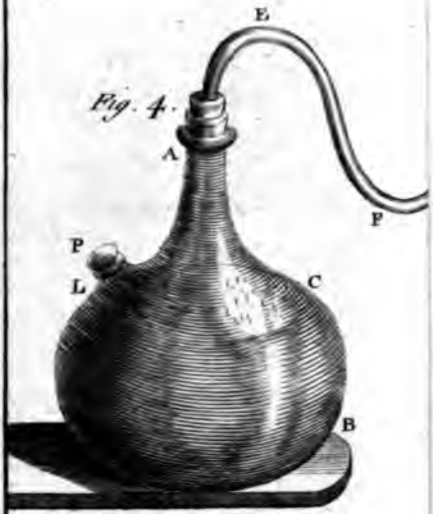
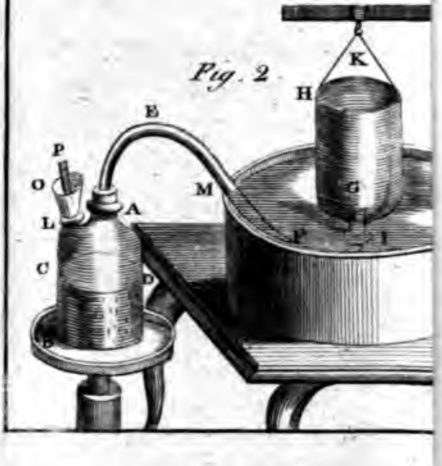
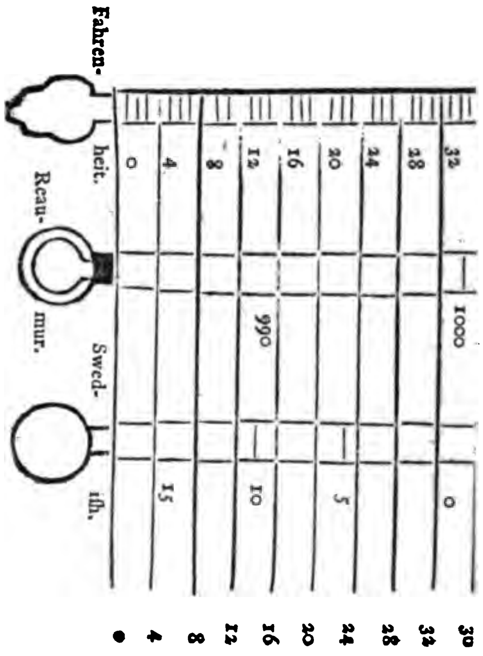


Fig. 2



BIBLIOTHECA · [illegible]

# COMPARATI


Fahren-heit.
Reau-mur.
Swed-ish.